PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY,

HELD AT PHILADELPHIA, FOR PROMOTING USEFUL KNOWLEDGE.

VOL. XIX. JANUARY TO JUNE, 1881. No. 108.

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Note. Six plates of the figs. described on page 58 (received too late to be bound with No. 107) are bound with this No. 108.

ERRATA.

Page 301, l. 27, read, continued *in* this channel, &c.

Page 301, ¶ 5, 5, read ¶ *5a*, *5b*.

Page 310, l. 10, read *Brant* for Brent.

Page 311, footnote, read *south*ern and *south*-western for northern and north-western.

Page 318, l. 31, read connection *with* Lake Huron.

Page 319, l. 5 from bottom, read *have been* excavated.

Page 323, l. 33, read lake *at* no very great distance.

Page 328, l. 34, read valley *from* Lake Erie.

Page 332, l. i., read westward, *it has* about.

Page 333, l. 16, read, refer *to* some buried, &c.

Page 352, *J.* F. Mansfield should read *I.* F. Mansfield.

PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY,

HELD AT PHILADELPHIA.

VOL. XIX. JANUARY TO JUNE, 1881. No. 108.

Stated Meeting, January 7, 1881.

Present, 8 members.

President, Mr. FRALEY, in the Chair.

Letters of acknowledgment were read from the Morgenländische Gesellschaft, Halle a. S., Nov. 30 (100 to 105; list), and from Prof. J. J. Stevenson (106).

A letter requesting exchanges was received from M. DeMilloux, Director of the Musée Guimet, Lyons. On motion, it was referred to the Committee on Publication with power to act.

A request from the Albany Institute for No. 101 to complete a set was allowed.

Donations for the Library were received from the Russian and Belgian Academies; the Flora Batava; the Geographical Societies in Paris and Bordeaux, London Astronomical and Meteorological Societies and Nature, Nautical Almanac of Spain, American Journal of Mathematics, Silliman's Journal, Dr. G. W. Hawes, the Wesleyan University, New Jersey Historical Society, Pennsylvania Board of Agriculture, H. C. Baird, H. C. Lewis, H. Phillips, Jr., O. T. Mason, and Smithsonian Institution.

An obituary notice of Peter McCall, was read by Mr. Henry Phillips, Jr.

Notes on Photodynamics, were read by Professor P. E. Chase.

PROC. AMER. PHILOS. SOC. XIX. 108. 2A. PRINTED FEBRUARY 21, 1881.

A note on the protection of oil-tanks from lightning stroke, by B. Howard Rand, M.D., was communicated through Dr. Greene.

Extracts were read from letters of Harrison Wright, Ph.D., respecting the Permian shells discovered in the highest strata of the Wilkesbarre anthracite basin by Dr. Charles F. Ingham, and referred to by him in his forthcoming History of Luzerne county.

The discovery by Prof. Spencer, of King's College, Nova Scotia, of a buried channel, following Grand river, deep enough to permit the preglacial drainage from Northwest Pennsylvania and Western New York to pass across Lake Erie and pass round into the head of Lake Ontario, was described by Mr. Lesley, and its importance insisted upon.

A colored model of the preglacial channel of the Clarion (Allegheny) river in Armstrong county, Pennsylvania, was exhibited.

A colored MS. map of parts of Lee, Wise and Scott counties, Virginia, by Prof. J. J. Stevenson, was communicated for the Proceedings. It continues (westward) and in part corrects the colored geological map of Scott, Russell and Tazewell counties, by J. P. Lesley, published in Volume X of the Proceedings, 1872.

A small map of Pennsylvania was exhibited, colored, to show the progress of the Geological Survey since 1874.

The report of the judges of the annual election was read, declaring the following officers duly elected for the ensuing year:

President.

Frederick Fraley.

Vice-Presidents.

Eli K. Price, E. Otis Kendall, John L. LeConte.

Secretaries.

Pliny E. Chase, George F. Barker, Daniel G. Brinton, J. P. Lesley.

Curators.

C. M. Cresson, Henry Phillips, Jr. George H. Horn.

Treasurer.

J. Sergeant Price.

Councillors for three years.

Daniel R. Goodwin, W. S. W. Ruschenberger,
Henry Winsor, William A. Ingham.

The meeting was then adjourned.

Obituary Notice of Peter McCall. By Henry Phillips, Jr.

(*Read before the American Philosophical Society, January 7,* 1881.)

The life of a lawyer whose heart was not hardened by the arduous duties of his career, but which, through threescore years and ten, never failed to respond to the calls of humanity; who passed along earth's pathway from the cradle to the grave, untainted by sordid ambitions or ignoble aims; in whose footsteps it would be an honor to tread, whose approbation would be a hall-mark to those fortunate enough to win it—the life of such a man is not written in sand. Such a man is an honor to his profession and to his city. Such a man was Peter McCall.

Peter McCall was born in the city of Philadelphia, on the 31st day of August, A. D. 1809, and departed this life at his summer residence, Overbrook, near Philadelphia, on the 30th day of October, A. D. 1880. He was descended from one of the oldest families in Pennsylvania, an account of whose genealogy is given in the Shippen Papers, edited by Mr. Thomas Balch. His father, also named Peter McCall, intermarried with Sarah Gibson, of whom were born John Gibson (born 1804, married at Tampico, Doña Josefa Beccerra), Charles Archibald (born 1806), Anna Maria (born 1807), and Peter, the subject of the present sketch.

Mr. McCall's education was commenced in Philadelphia, and completed at Princeton, where he graduated with distinction in the class of 1826. He then began the study of the law in the office of Hon. Joseph R. Ingersoll, surrounded by fellow students, who all in later years rose to high legal eminence, and some of whom have occupied the judicial station. Pursuing his studies with zealous assiduity, he was admitted to the Philadelphia Bar on the first day of November, A. D. 1830, and from that day, until a few months since, when increasing infirmities compelled him to relinquish the practice of his profession, his career of usefulness was untiring and unceasing. Had he lived but one day longer, he would have completed a full half century of active work, an event which the Law Association of this city, of which he had been for years a prominent member, and in which he had held the office of Chancellor from 1873 to the day of his death, was preparing to celebrate in an appropriate manner. Upon the walls of its library hangs an excellent portrait of Mr. McCall, painted by Uhle, which a few years since was presented to the Association by the Chancellor's former office

students. His predecessors in that honorable position had always been like himself, men of the highest rank, whose names the lawyers of the entire land were accustomed to utter with veneration, respect and esteem; Rawle, Duponceau, Sergeant, Binney, Ingersoll and Meredith. Names to be handed, with the best traditions of the Bar, down to its latest days.

In 1846, Mr. McCall married Jane Byrd Mercer, at Cedar Park, West River, Maryland, the residence of her father, Col. John Mercer. Of this marriage were born Catherine, John Mercer, Edith (married to Dr. John M. Keating, of this city), Gertrude, Richard Cadwalader, Robert Kemble, Jane Byrd and Mary. Of these children only the youngest daughters survive, to mourn with their mother their great loss. During the years 1837, 1853 and 1870, Mr. McCall traveled in Europe, storing his mind with the rich harvests of Old World knowledge, while enjoying a brief respite from his arduous labors.

Although no politician, in the now-a-days sadly abused signification of the term, Mr. McCall always felt deep interest in the progress of public affairs, and never shrank from accepting such duties as it pleased his fellow-citizens to call upon him to undertake. He sat in the Councils of the City for several terms, and in 1844 was elected Mayor of the City, as the candidate of the Whig party, defeating by a large vote Samuel Badger, the Democratic, and E. W. Keyser, the Native American candidate. This was to Mr. McCall, a great compliment, paid in a time of strong political excitement by the citizens, who understood and appreciated sterling honor and integrity.

On the 18th day of April, 1851, he was chosen a member of our Society, but owing to the continual pressure of other duties, never took an active part in our labors.

He was for many years one of the Trustees of the University of Pennsylvania, in whose law schools, he, until comparatively recently filled the chair of practice, pleading, and evidence.

Mr. McCall was for a time a member of the Vestry of Christ Church (Protestant Episcopal), and also Warden, but after long and faithful services rendered by him to the cause of religion and of the Church, in the early days of the war, his connection with it came to an end.

While the public record of Mr. McCall's life is mainly that of a professional man, yet he was a cultured scholar of refined tastes and great attainments. But he very rarely permitted himself to be seduced by the fascinations of the lighter sciences from the pursuit of the life-long duties to which he had dedicated his career. He knew that the law was a jealous and exacting mistress, in whose service there could be no loitering by the wayside or stepping from the beaten track to cull the flowers of literary success; that it required the devotion of a lifetime, sharing no divided attention, brooking no divided empire. The chief occasions upon which Mr. McCall would permit his literary talents to be observed, were in obituary addresses upon deceased members of our Bar, which he delivered by request, from time to time, in accordance with the kindly usage of the

profession, and his special gifts of eloquence and good taste on such occasions, were always exhibited to great advantage.

He delivered, however, some orations, which have been published, and are all distinguished by a vigorous and elegant style,* clear thought and polished judgment.

Prominent in Mr. McCall's character were his kindliness, gentleness and loving heart. As Judge Hare well remarked,† "he was one of those exceptional men whom nature seems to have formed for virtue, and who are endowed by her with graces which others derive only from education, or through the influences of philosophy and religion. His distinguishing characteristics were singleness of purpose, an entire purity of heart and life, a gentleness that neither took nor gave offence; a charity large enough to embrace all mankind; an instinctive aversion to whatever was low or base; an intuitive perception of the line of right. * * * * He was in short one in whom the various attributes of goodness were so nicely blended in a harmonious whole that he seemed less than he really was; and it may be said of him, as it was of Washington, that he would have been greater in the world's eye had he been less virtuous."

In his earliest life he had set before himself a standard of virtuous excellence to which he proposed to attain, and below which he should never descend. He wrote in his diary upon the nineteenth anniversary of his birthday, "The prospect is fair. May it never be clouded by dishonor or the consciousness of having done an ill deed."

Throughout all the trials, great and small of daily life, he remained true to his principles, the ideal advocate, the man of honor, the accomplished gentleman.

He was a bold man, strong in the consciousness of rectitude, and not for all the world could give, the smiles of friends, the pleasures of power, did he ever for an instant hesitate to obey the dictates of his conscience, regardless of the penalties to be paid for his independence. "He was faithful to his convictions of truth when such fidelity cost dear."

It would not be proper that I should consume so much of the time of our Society as would be really requisite to delineate Mr. McCall's life, and I must close with this imperfect sketch of the main features of his career. But I leave it with the less regret, knowing that to the accomplished hand of Isaac Hazlehurst, the life-long friend of Mr. McCall, has been entrusted by the Law Association, the duty of preparing a memorial address, and I am sure that his eloquent pen will do justice to departed worth; that he will not fail to suitably commemorate

"That best portion of a good man's life,
"His little, nameless, unremembered acts
"Of kindness and of love."

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*November 29th, 1832. Annual discourse before the Historical Society of Pennsylvania.

January 4th, 1836. Oration before the Zelosophic Society of the University of Pennsylvania.

September 5th, 1838. A discourse before the Law Academy of Philadelphia.

† Bar meeting held on November 4, 1880.

Note on the Protection of Oil Tanks from Lightning Stroke. By B. Howard Rand, M.D.

(*Read before the American Philsophical Society, January* 7, 1881.)

The frequency of the ignitions of the contents of tanks used for storing mineral oil, with the concomitant destruction of property and life has attracted much attention. The suggestions as to the means of prevention have been crude.

It is my purpose to offer a theory as to the cause, and a means of avoiding the mischief.

An air-tight tank of metal, or one sheathed with metal, would, if filled with crude rock-oil, or even with loose gunpowder, be safe from damage from lightning stroke. It would be no more in danger of the thunderbolt than a log-cabin similarly situated. If struck it would escape unharmed. The late Professor Clerk Maxwell suggested the protection of powder-magazines by sheathing them with metal. Professor Tait recommends the investigator of the so-called ball or globe-lightning to wear a suit of light copper armor. It would be safer to add a thorough ground connection. This could be made in most cases to the pipes.

As the level of the oil in the tanks must vary with the rate of the inflow and outflow through the pipes, openings are necessary to allow the egress or ingress of air. There may be occasion to lift the lid at times.

From the necessary openings and leaks around the lids, the light hydrocarbon vapours escape. These mingling with the air form an explosive mixture like the fire-damp of mines, which, if ignited at a distance of even hundreds of feet, will travel back and set fire to the contents of the tank.

To prevent this I suggest that the necessary vent-holes be protected with safety tubes after the plan of Hemming's, or with several layers of fine wire gauze, strong enough to resist any probable breaking by mechanical shock. These should be protected from dust and wet by loosely fitting covers.

On the approach of a thunder-storm, the outflow should be checked, so as to avoid an indraught, which we so well know will render useless in many cases the protecting metallic mesh.

Where moveable covers are used, they should have the ordinary seal used in telescopic gas-holders. Glycerine in the seal is recommended as it does not evaporate and is not affected by changes of temperature within the limits of ordinary atmospheric fluctuations.

Where it is necessary to introduce chemical agents in the process of refining, the well known safety traps should be used.

Stated Meeting, January 21, 1881.

Present, 12 members.

Vice-President, Mr. ELI K. PRICE, in the Chair.

A letter of envoy was received from the Central Observatory, St. Petersburg.

A letter of acknowledgment was received from Prof. L. Rutimeyer, Basel, dated Jan. 1, 1881 (104, 105).

A circular was received from the Census Bureau.

Donations for the Library were received from the Statistical Bureau at Stockholm; the Geographical Societies of St. Petersburg, Paris and Bordeaux; Herr E. Reyer, of Wien; Zoologischer Anzeiger, Leipsig; Revue Politique, Paris; Academia dei Lincei, Rome; Revista Euskara, Pamplona; Nature, Journal of Forestry, and Chemists' Journal, London; Mr. Thos. Henry Thomas, Cardiff, Wales; Canadian Naturalist, Montreal; Boston Society of Natural History; Franklin Institute, Medical News, Journal of the Medical Sciences, Journal of Pharmacy, Mr. Henry Phillips, Jr. and Mr. Franklin B. Gowen, Philadelphia; Wyoming Historical and Geological Society, Wilkes-Barre; Commissioner of Education, and Department of Engineers, Washington; California Academy of Sciences, San Francisco; Sociéta de Geographica y Estadistica, Revista Cientifica, and Ministerio de Fomento, Mexico.

The death of the Rev. Humphrey Lloyd, D.D., of Dublin, Jan. 17, 1881, aged 80, was announced by the Secretary.

A geological reconnaisance of parts of Lee, Wise, Scott and Washington counties, Va. by J. J. Stevenson, with six small cuts, and the colored map (mentioned at the last meeting) was presented.

Mr. Lesley was elected Librarian for the ensuing year.

The following members were placed upon the Standing Committees:

Finance.

E. K. Price,
B. V. Marsh,
Henry Winsor.

Hall.

S. W. Roberts,
J. S. Price,
W. A. Ingham.

Publication.

J. L. LeConte,
D. G. Brinton,
E. Thomson,
C. M. Cresson,
G. H. Horn.

Library.

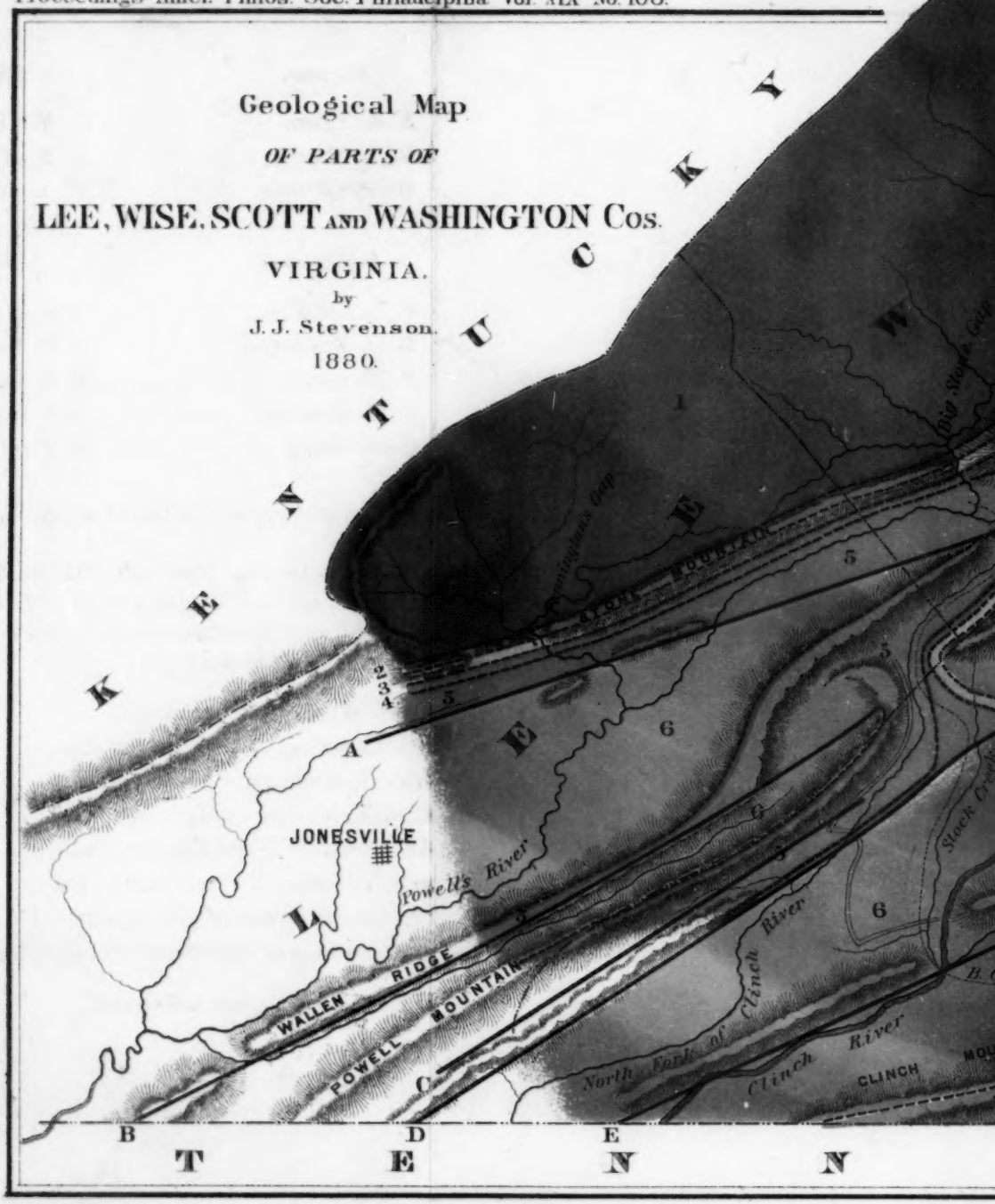
E. K. Price,
C. P. Krauth,
R. S. Kenderdine,
E. J. Houston,
H. Phillips, Jr.

The annual reading of the list of surviving members was postponed.

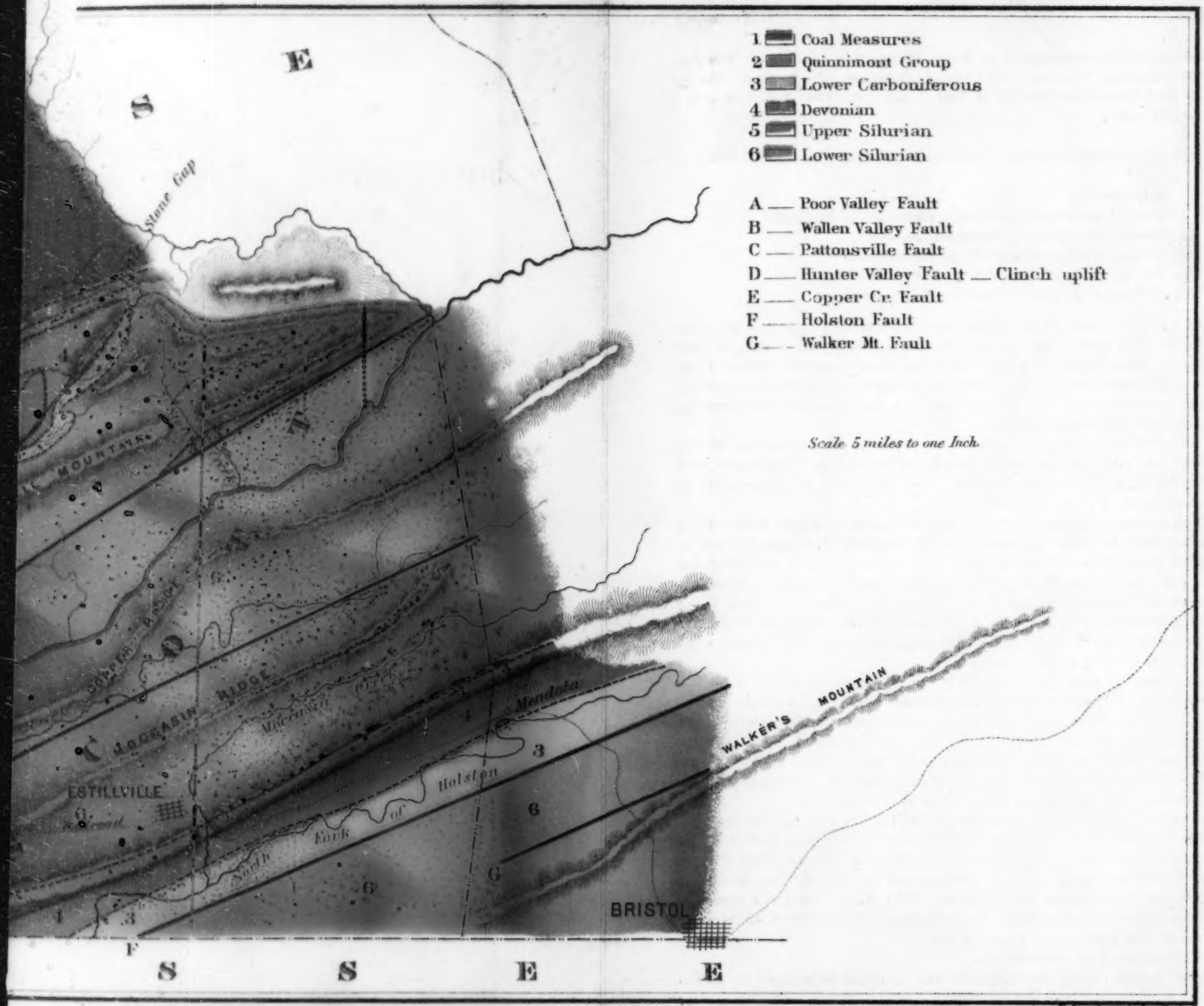
Pending nominations Nos. 909; 920 to 926 were read, spoken to and ballotted for; on scrutiny of the ballot boxes by the presiding officer the following were declared duly elected members of the Society:

Lewis S. Ware, of Philadelphia.
Joseph Lovering, of Cambridge, Mass.
Charles G. Ames, of Philadelphia.
Edward Y. McCauley, U. S. N.
Addison May, of West Chester, Pa.
Joseph J. Lewis, of West Chester, Pa.
Henry Carvill Lewis, of Germantown, Pa.
Dr. Charles Stewart Wurts, of Philadelphia.

And the meeting was adjourned.


Geological Map
OF PARTS OF
LEE, WISE, SCOTT AND WASHINGTON Cos.
VIRGINIA.
by
J. J. Stevenson.
1880.
KENTUCKY
TENNESSEE
JONESVILLE
Powell's River
WALLEN RIDGE
POWELL MOUNTAIN
Cumberland Gap
Big Stone Gap
North Fork of Clinch River
Clinch River
CLINCH
Stock Creek
A
B
C
D
E
1
2
3
4
5
6

E
S
Stone Gap
Big Stone Gap
POWELL MOUNTAIN
Stock Creek
COPPER RIDGE
MOCCASIN RIDGE
Moccasin Creek
Mendota
ESTILLVILLE
B. C. & I. Railroad
North Fork of Holston
MOUNTAIN
E
S
S
E
F



T. Sinclair & Son Lith.

A Geological Reconnaissance of Parts of Lee, Wise, Scott and Washington Counties, Virginia. By John J. Stevenson, Professor of Geology in the University of the City of New York. (*With six wood cuts and a colored map.*)

(*Read before the American Philosophical Society, January* 21, 1881.)

Introduction.
I. *General structure of the area; description of the faults.*
II. *General description of the several groups.*
III. *Geology of the area drained by Powell river.*
IV. *Geology of the area drained by Clinch river.*
V. *Geology of the area drained by Holston river.*

In a former memoir,* the writer described a small part of Lee and Wise counties, and gave some casual observations respecting a part of Scott county. Examination of a larger area has shown that two serious errors, due to too ready acceptance of information respecting localities not visited, occur in that memoir, and has led also to a change in opinion respecting the structure of Stone mountain.

The counties examined occupy the extreme south-west corner of Virginia; Lee being in the angle between Kentucky and Tennessee, with Wise adjoining it along the Kentucky line, while Scott and Washington lie next along the Tennessee border.

The surface is broken by rudely parallel mountain ranges, separated by narrow valleys. The distance along the shortest line from the city of Bristol to the Kentucky border is barely fifty miles, yet in following that line one must cross Walker, Brushy and Clinch mountains; Moccasin, Copper and Buckner's ridges, Powell mountain, Wallen's and Poor Valley ridges, Stone and Black mountains. Several of these ridges are single, and have abrupt slopes, while others are compound, and their slopes afford grades not too difficult for wagons.

The area between the Great Valley of Virginia and Moccasin ridge is drained by the Holston river; that between Moccasin ridge and Powell mountain, by Clinch river; and that beyond Powell mountain to the Kentucky line, by Powell river. The Clinch and Holston unite to form the Tennessee river, and Powell river enters the former at not far from Knoxville. Of these rivers, the Powell rises within the area examined; the others have their sources far beyond toward the north-east.

A narrow strip of this region along the Kentucky border has been examined by Mr. P. N. Moore, of the Kentucky Geological Survey, and a summary account of his observations is given in the reports of that Survey, Vol. IV. Prof. Lesley's work, as described in his memoir,† is slightly overlapped by the writer's examination. The whole region was examined during the survey under Prof. W. B. Rogers. One is compelled to regret

* Read before this Society, August 20, 1880.
† Proceedings of this Society, 1872.

that the reports of that survey are so rare; since the map prepared by Prof. Rogers and published in "The Resources of Virginia," shows that the structure was admirably worked out. The faults are clearly shown on that map, and the distinction between the limestones of the Lower Carboniferous and the Lower Silurian was determined accurately, though at that time there was little aside from physical characters to depend on for identification. When it is remembered that the region was even more thinly settled forty years ago than it is now, one may not refrain from acknowledging the skill and patience with which the structure was worked out at that early day.

To obtain the material given in this memoir, one section was followed from Black mountain almost directly to Bristol; a second from Pennington's gap in Stone mountain to the Tennessee line by way of Estillville and Moccasin gap through Clinch mountains; shorter sections were followed across Moccasin and Copper ridges; while several of the faults were followed for from ten to twenty miles. Necessarily, many interesting details were neglected, and some points of importance were left undecided, as the object of the reconnaissance was purely economic.

No map worthy of the name exists, and that accompanying this memoir is based on the old State map, made in 1825. Some gross topographical errors have been corrected partially; others remain, which interfere seriously with a proper presentation of the geology; but to correct these would involve a complete reconstruction of the whole.

I. General Structure of the Area.

The structure is monoclinal, and the prevailing dip is toward the southeast. The one exception is in the area between Black mountain and the summit of Powell mountain, where, as will be shown, a cracked anticlinal exists. In passing from Black mountain to the Valley of Virginia at Bristol, one crosses

1. *The fault of Poor Valley ridge.*
2. *The Wallen valley fault.*
3. *The Pattonsville fault.*
4. *The Hunter valley fault, or Clinch river uplift of Lesley.*
5. *The fault of Copper creek.*
6. *The fault of the North Fork of Holston.*
7. *The fault of Walker mountain.*

Black mountain is a rude mass, which owes its origin solely to erosion. It is the dividing ridge between the waters of the Cumberland and those of Powell and Clinch rivers. Its course is irregular but bears westward and southward until, at a little way west from Pennington's gap in Stone mountain, it unites with the latter ridge. The only rocks exposed in this mountain are those of the Coal Measures, and their dip is northward, or north north-west. Toward Stone mountain, the dip suddenly increases until in that ridge it becomes almost, and at some places, wholly vertical.

Stone mountain is a bold narrow ridge with a N. 67° E. course, which

begins not far beyond the Little Stone gap and continues thence into Tennessee. It was examined from Little Stone gap to nearly three miles beyond Pennington's gap, a distance of nearly thirty miles, in which it has but two water gaps, those of Powell river and its North Fork, or, as they are commonly known, Big Stone and Pennington's gaps. A wind gap, the Little Stone, affords passage for the turnpike leading from Jonesville to Gladesville.

In his former memoir, the writer regarded Stone mountain as a fault, but he is now convinced from the conditions observed at Pennington's gap, that the mountain is but the side of an exceedingly abrupt fold, as will be explained in another paragraph.

In the Poor Valley, which follows the southerly foot of Stone mountain, the Devonian shales are shown underlying the Lower Carboniferous. At the head of the valley, the Lower Carboniferous is well shown in the divide between the South Fork of Powell river and the waters of Stony creek, where it is in direct contact with the Lower Carboniferous of Stone mountain. In the divide, it dips gently toward the south-east, while in Stone mountain the dip is almost vertical, the incline being toward the north-west or north north-west. The dips in the mountain become sharper toward the west, being 70 degrees in Big Stone gap, and 90 degrees in Pennington's gap. The rocks shown in the mountain gaps are the Lower Carboniferous, the Quinnimont group and the lower beds of the Coal Measures.

The fault of Poor Valley ridge must be described before the structure of Stone mountain can be fully explained. This fault is very nearly parallel to Stone mountain, though the increasing strength of the thrust, by turning the rocks directly on edge, has diminished the interval materially in the vicinity of Pennington's gap. The distance between the two ridges varies from a mile to a mile and a half. At its eastern extremity, the fault begins in a gentle anticlinal nearly opposite Little Stone gap. A crack develops in this anticlinal near the gap, by which the South Fork of Powell river crosses it, and increases rapidly in importance westward. The Devonian shales cross the anticlinal at its origin, while in the divide at the head of the valley, the Lower Carboniferous and part also of the Quinnimont group pass over it so as to be continuous with the rocks of Stone mountain. But the anticlinal soon becomes bold, and the fault develops, so that the ridge is divided below the mouth of South Fork of Powell into Poor Valley ridge and Wallen's ridge. There the extent of the fault is shown, for the Clinton is in direct contact with the middle shales of the Knox group. Poor Valley ridge continues westward to beyond the Tennessee line, and varies much in height and width. It is composed chiefly of Clinton rocks, while the Lower Helderberg, Oriskany and Hamilton occur in the narrow valley between it and Stone mountain.

The writer has stated in another paper that Stone mountain is a fault, and that it is the continuation of the *Clinch river uplift* described by Prof. Lesley. Mr. Moore, in the report of his reconnaissance along the border

of Kentucky and Virginia, maintains that Stone mountain is not a fault, but that it is a sharp fold and a typical example of the Cumberland mountain structure. The exposures beyond Little Stone gap and at Pennington's gap show this to be true. It is precisely like the structure of Brush mountain, Kentucky, of which an illustration is given in a long cross-section accompanying another of Mr. Moore's reports. At Pennington's gap the succession of Upper Silurian, Devonian and Lower Carboniferous is clear, and all the groups are conformable. Figures 1, 2 and 3 exhibit the structure of the whole fold; No. 1 being a cross section from the northerly slope of Stone mountain to Powell mountain; No. 2, a similar section through Big Stone gap, and No. 3, the section from Pennington's gap to Wallen's ridge.

FIG. 1.—Section from Stone mountain at Little Stone gap to Powell mountain. *a*, Slope of Black mountain; *b*, Stone mountain; *c*, Powell mountain; 1, Coal Measures; 2, Quinnimont group; 3, Lower Carboniferous; 4, Devonian; 5, Upper Silurian; 6, Lower Silurian.

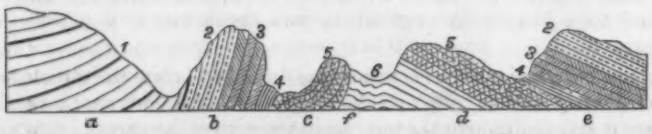


FIG. 2.—Section from Stone mountain at Big Stone gap to Powell mountain. *a*, Slope of Black mountain; *b*, Stone mountain; *c*, Poor Valley ridge; *d*, Wallen's ridge; *e*, Powell mountain; *f*, fault of Poor Valley ridge. Numbers as in preceding figure.

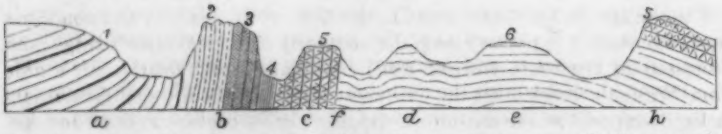


FIG. 3.—Section from Stone mountain at Pennington's gap to Wallen's ridge. *a*, Slope of Black mountain; *b*, Stone mountain; *c*, Poor Valley ridge; *d*, Chestnut ridge; *e*, Elk Knob; *h*, Wallen's ridge; *f*, fault of Poor Valley ridge. Numbers as in preceding figures.

The change of structure beyond the fault of Poor Valley ridge will be explained in its own place.

Wallen's ridge includes the eastern extremity of Poor Valley ridge, and the two ridges become separate only beyond the mouth of South Fork of Powell river. Lower Silurian rocks are shown on its northerly side, Medina sandstone forms the crest, while Lower Helderberg and Oriskany are shown on the southerly slope. The structure, where the ridge first separates itself from Poor Valley ridge, is shown in Fig. 2, which represents the cross-section from Poor Valley ridge fault across Turkey Cove,

and the mountain to Powell mountain. There the ridge is narrow; but at some miles further west the conditions are as in Fig. 3, which shows the section from the Poor Valley fault on North Fork of Powell to the Wallen Valley fault near Stickleyville. Here instead of the single ridge seen at the Turkey Cove there are three ridges, known as Chestnut ridge, Elk Knob and Wallen's ridge. The folds in Chestnut ridge are exceedingly complex, and are well shown in the gap by which the North Fork of Powell river passes through it. The beds are folded without crushing, though some of the angles are as sharp and close as the bent elbow. But in Elk Knob the strata are practically horizontal until near the southerly slope where the dip becomes nearly 15 degrees. The rate increases toward Wallen's ridge as well as in the ridge, until, along the summit line, the Medina dips at nearly 40 degrees. The Upper Silurian rocks are reached on the southerly slope of the ridge.

The relations of Wallen's ridge to Powell mountain are somewhat complicated by the Wallen Valley fault, which begins at the head of Wallen's valley. As far as could be ascertained, no traces of that fault exist further east. That part of Powell mountain which lies east from Slemp's gap, through which the North Fork of Clinch flows, has a very different structure from that of the part lying west from that gap. The eastern division is but a continuation of Wallen's ridge, the separation being due solely to erosion; for, on the bold bluff which Powell mountain presents to the valleys of the South Fork of Powell river and the North Fork of Clinch river, the section is but a continuation of that shown on the slope of Wallen ridge; and the Lower Helderberg, Oriskany, Hamilton, Lower Carboniferous and Quinnimont group appear in regular succession, while the Quinnimont group covers the southerly slope of the mountain to where it is cut off by the Hunter Valley fault. The conditions observed on this side of Powell mountain will be described in connection with that fault.

The Wallen Valley fault begins at the head of that valley, and continues into Tennessee. It passes along the southerly side of Wallen's ridge, and is crossed by the Jonesville and Estillville road at, say, nearly half a mile from Wallen's creek. On its northerly side are the Lower Helderberg rocks, ill-exposed where examined, dipping almost south-east at 45 degrees, while the limestones of Formation III are shown on the southerly side dipping in the same direction at 30 degrees. The upper part of No. II is shown near the fault, but only a small part of that group is brought up where the examinations were made. It is not wholly certain that this fault begins within Wallen's valley, but no traces of it were seen on the other side of the mountain, where, however, the forest is dense, and exposures are few and not satisfactory. It is certainly absent from the valley of North Fork of Clinch at three miles further up. This fault is important economically, for, in great measure owing to its sudden development, Powell mountain west from Slemp's gap has been so far elevated that the Devonian, Lower Carboniferous and Quinnimont group, still present on the other division of the mountain, have been wholly removed by erosion.

Powell mountain west from Slemp's gap is but a repetition of Wallen's ridge as shown on the opposite side of Wallen valley. The limestones and shales of Formation III are exposed on its northerly side, Medina sandstone follows its crest, while the Lower Helderberg, Oriskany and a fragment of the Hamilton are shown on its southerly side. These rocks are suddenly cut off by the

Pattonsville fault, which is marked by a low ridge at, say, two-thirds of a mile from the crest of Powell mountain. No evidence of its presence was found beyond the railroad line, and, in all probability, it originates very near that line. The structure between the Wallen's valley fault and the Hunter Valley fault (Clinch uplift) is shown in Fig. 4. This fault

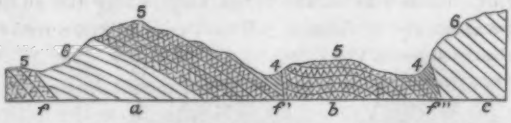


FIG. 4.—Cross-section through Powell mountain from the Wallen Valley fault to the Hunter Valley fault in Buckner's ridge. *a*, Powell mountain *b*, Pattonsville ridge; *c*, Buckner's ridge; *f*, Wallen's Valley fault; *f'*, Pattonsville fault; *f''*, Hunter Valley fault or Clinch uplift. Numbers as in Fig. 1.

brings up the Lower Helderberg rocks against the Hamilton shales; the former describe a shallow synclinal and low anticlinal, so that, before reaching the North Fork of Clinch river, the Hamilton shales are again exposed, dipping very sharply toward the south-east. The details of this fault cannot be expressed on the map, owing to the narrowness of the area affected by it. It is evidently parallel with the Wallen Valley fault, and it is responsible for the absence of the Lower Carboniferous rocks from the valley at the southerly foot of Powell mountain. This fault, according to Prof. Safford's map, does not exist in Tennessee.

The Hunter Valley fault is the same with the *Clinch river uplift*, which is so fully described by Prof. Lesley in his memoir on the geology of Wise and Tazewell counties.* As it lies at a considerable distance from Clinch river within the area under consideration, it is best to apply to it a local name. Its direction, as laid down on the map, does some violence to the truth, but the writer has preferred to give the direction of the fault properly, even though in so doing it is thrown somewhat out of its geographical relation. This fault enters Scott county near its north-western corner, whence it follows an almost straight line to the gap made through it by the North Fork of Clinch river, being crossed very near the head of Powder Mill gap by the Bristol railroad, and by the Jonesville and Estillville road at barely two miles from Pattonsville. It is crossed but once by the North Fork of Clinch.

This is probably the most violent of the faults observed within the region examined. The rocks on both sides of the fracture are bent upward, and, at more than one locality, the structure is distinctly that of a cracked anticlinal. The energy of the lift varied, for along a very considerable dis-

* Proceedings of this Society, 1872.

tance, the Hamilton shales are the lowest beds exposed on the northerly side of the fault, while at several localities lower groups, even down to the Medina, have been brought up.

At the gap of North Fork of Clinch, the Hamilton shales are well exposed on the northerly side at some distance from the line of break, where they are abnormally thick, show a strike N. 80° E. mag. and are dipping toward the fault at 40 degrees. Some sandstones seen between these and the foot of Buckner's ridge may represent the Lower Helderberg, and the Clinton rocks are exposed at the foot of the ridge. Whether or not the succession is complete, was not determined, as the side of the ridge is deeply covered with debris; but fragments of quartzite-like white sandstone were seen, which bear much resemblance to the Medina sandstone as shown in Moccasin gap of Clinch mountain. The exposures are all poor and the Clinton was recognized only by its fossil ore. The probable structure is doubtless as represented in Fig. 5.

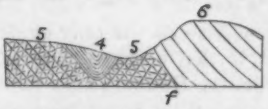


FIG. 5.—Probable structure of Hunter Valley fault at North Fork gap. *f*, Hunter Valley fault. Numbers as in Fig. 1.

The fault is crossed by the Jonesville and Estillville road at two or three miles further east. There the Hamilton shales, shown in the river "bottom," appear to be in contact with the calcareous sandstones of the Knox group, which form a bold wall along the line of fault. These shales are dipping toward the fault, but they may be folded as they are near the North Fork gap. At four or five miles further east, one has passed beyond the influence of the Pattonsville and Wallen Valley faults, and has reached the southerly foot of Powell mountain in Hunter valley. Standing here at the railroad line, he can follow with his eye, the course of the fault in each direction, for it is marked by the low and sharply serrate ridge known as Buckner's ridge. This seems to follow an almost straight line from the county line to the North Fork gap.

In the Hunter valley, the wall of Knox sandstone is as well marked as it is along the North Fork of Clinch, while on the other side the Quinnimont group covers the slope of Powell mountain and extends into the valley. Near the end of the valley, the North Gap structure is repeated, but only the Lower Carboniferous and the Devonian are turned up. Beyond this, no exposures exhibiting the structure were seen until Stony creek was approached. The sandstone wall is distinct all the way, but the debris from the conglomerates covers the whole "bottom" deeply even to the foot of the wall. Toward Stony creek, the structure becomes very similar to that observed in the North Fork gap, but time did not admit of working out its details. The Lower Carboniferous, the Devonian and the Silurian as far down as the Clinton at least, were recognized on Stony creek between the last exposure of the Quinnimont series and the wall of Knox sandstone.

The general structure, then, must be as represented in Fig. 6, which shows also the structure of Powell mountain. The Quinnimont series caps the

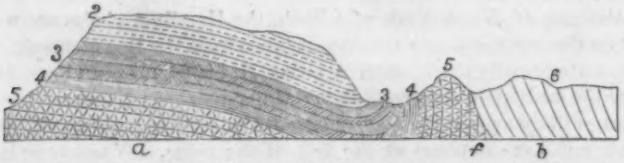


FIG. 6.—Cross-section along Stony creek through Powell mountain and Buckner's ridge. *a*, Powell mountain; *b*, Buckner's ridge. Numbers as in Fig. 1.

bluff overlooking the valley of South Fork of Powell river. Thence for several miles the dip is gentle, but within somewhat more than a mile from the fault it suddenly increases, becoming rather more than 30 degrees, and at the last exposure of the rock it is nearly 45 degrees. This change in rate is so abrupt that where the narrow valley follows the line of change, a fracture at once suggests itself as the only explanation of the condition.

It is altogether probable that a close, sharp fold exists within two or three miles south-east from the Hunter Valley fault. The shales alongside of Clinch river above the mouth of Stony creek are violently twisted and the plications are as close as those frequently seen in Archæan schists. The shales themselves in many places are jointed and have an indistinct slaty cleavage; but they show no other signs of metamorphism. The rock forming the bluff on the opposite side of the river is a pyritous sandy limestone very like that which is at the base of the Knox group. A similar condition was observed in crossing Buckner's ridge along the Jonesville and Estillville road, at probably fourteen miles west from Stony creek.

Copper ridge lies on the southerly side of Clinch river, until within six miles of the Tennessee line, where it is crossed by that river. It is a monoclinal, but the dip is irregular, as is shown along the Stony creek road as well as along the road leading from Gray's ford on Clinch river to Nickelsville on the southerly slope of the ridge. The dip at Clinch river is not far from 40 degrees; at two miles from the river, the beds are almost horizontal; but toward the southerly side of the ridge, the dip increases to almost 33 degrees. The only rocks exposed in this ridge belong to the Lower Silurian groups. Prof. Lesley, on the map accompanying his memoir on Wise and Tazewell counties, colors Clinton along the southerly side of this ridge; but no Clinton is present within Scott county.* The structure of the ridge in this county suggests the possibility that, at no great distance eastward, the ridge may consist of a double anticlinal with a shallow synclinal along the crest, in which some Upper Silurian rocks may be held.

The Copper Creek Fault, as appears from Prof. Lesley's map, extends for a considerable distance into Russell county, which adjoins Scott on the north-east. It was examined by the writer very near the Russell county

* Prof. Lesley did not visit this portion of Scott county.

line; also where the Estillville and Stony creek road crosses Copper creek; and in the Clinch river gap. This fault continues into Tennessee; it brings up the base of the upper division of the Knox group against the higher beds of the Trenton and Nashville group. *Moccasin ridge*, lying between Copper and Moccasin creeks, and owing its existence to the Copper creek fault, is a monoclinal with a dip throughout of little more than 30 degrees. It consists of rocks belonging to the Lower Silurian. Moccasin valley, eroded by the creek of the same name, separates Moccasin ridge from Clinch mountain, in which one finds a continuation of the series. The upper shales of No. III are shown on the northerly side, while the Medina sandstone forms the crest. Southerly dips continue beyond the crest of Clinch mountain, across the Poor valley and to the southerly side of Brushy mountain, where one reaches the

Fault of the North Fork of Holston.—Along the line of the Bristol railroad, this fault is reached at about three miles from the river, the distance being measured along the shortest line; but it is at somewhat more than six miles by the railroad. Near the Tennessee line, it is little more than one mile from the river at the mouth of Moccasin creek. It extends for a long distance toward the north-east and reaches into Tennessee. This fault is not inferior to the Hunter Valley fault, for it brings up the middle division of the Knox group against the very top of the Lower Carboniferous. But it shows none of the complex structure seen along the Hunter Valley fault. Wherever examined, the Lower Carboniferous rocks dip toward the fault and are not turned up near the line of fracture. There is, however, some crumpling at a little way from the break. A synclinal was seen on the North Fork of Holston at but a little way above the mouth of Moccasin creek, and an anticlinal is described at a little way further south-east. The same condition was seen along the railroad line beyond North Fork of Holston. Abrupt changes of dip occur in the Lower Carboniferous rocks along several lines in Brushy mountain.

The Walker Mountain fault follows the northerly side of that mountain and brings up the base of the Knox group so as to be in contact with the top of the Trenton and Nashville group. This fault extends for at least eight miles. No study of structure was made between Walker mountain and Bristol, where the line of section ended. In all probability, however, a small fault occurs in that interval, for the cherty beds at the top of the Knox group occur in the immediate vicinity of Bristol.

The extent of the several faults is approximately as follows:

1.	*Fault of Poor valley*	2400′
2.	*Wallen Valley fault*	2800′
3.	*Pattonsville fault*	500′
4.	*Hunter Valley fault* or *Clinch River uplift*	8000′
5.	*Copper creek fault*	3000′
6.	*Holston fault*	7500′
7.	*Fault of Walker mountain*	3000′

The Holston and Hunter Valley faults were much greater originally, for

the Coal Measures, without doubt, covered Powell Mountain at one time, and it is equally probable that both the Quinnimont series and the Coal Measures existed at one time on Brushy mountain. It is altogether probable that on some of the high knobs of Brushy mountain, the Quinnimont beds have been spared by erosion. In such case, the extent of the Clinch river uplift would be not far from 10,500 feet and that of the Holston uplift very nearly 11,000 feet.

Poor Valley ridge is crossed by the South Fork of Powell river, by Powell river itself and by the North Fork: Wallen's creek crosses the Wallen Valley fault; the Clinch River uplift is crossed by the North Fork of Clinch, by Stock creek, by both branches of Cove creek and by several forks of Stony creek; Copper creek fault is crossed by Clinch river, and Copper creek in its windings crosses it several times; the Holston fault is crossed by a stream entering the river near the mouth of Moccasin creek and by Abraham's creek; while the Walker Mountain fault is crossed by the stream along which the railroad passes through the mountain.

II. General Description of the Groups.

The section exposed within the region examined extends from the Coal Measures to the base of the Knox group as recognized by Prof. Safford in Tennessee. Lower rocks are reached in the Great Valley of Virginia, which is drained by the South Fork of Holston river, but the reconnaissance stopped at Walker mountain on the northerly side of the Valley. Some of the groups show peculiarities not observed by Profs. Lesley and Fontaine in the area further east or by Prof. Safford in Tennessee.

The Upper Carboniferous.

The Upper Carboniferous is represented by the Coal Measures and the Quinnimont group or Seral (Pottsville) Conglomerate.

The Coal Measures.

The Coal Measures are found north from Stone mountain, and extend beyond Black mountain into Kentucky. Their thickness, as determined partly by estimate but mostly by barometric measurement, is not far from 2000 feet along Roaring Fork of Powell river and its tributary, Calahan's creek; but the highest part of Black mountain was not reached, since, according to Mr. Moore's barometric determination, the summit of that mountain at the head of Looney branch is 2200 feet above the Poor branch of Cumberland river; so that the thickness of Coal Measures is not less than 2500 feet, or somewhat less than that observed in the south-western part of Pennsylvania. There was no opportunity during the recent reconnaissance to complete the detailed section of these measures, and the highest 500 feet of the section given in the former memoir still remains unexamined in detail.

This area is not more than ten miles wide, for, according to the report on Mr. Moore's reconnaissance, already referred to, the Coal Measures are

cut off in Kentucky by the Pine Mountain fault. The basin begins in Tennessee, where it forms Prof. Safford's north-eastern division of the coal-field, and occupies the high lands of Morgan, Anderson, Scott, Campbell and Claiborne counties, north from the Emery river and east from a line passing through Huntsville and Montgomery. Prof. Safford found there 2100 feet of measures, in which *nine* beds of *coal* were seen, varying from one to six feet in thickness. These beds of the north-eastern district are, in part at least, above those of the other districts of the Tennessee coal-field, which belong not to the Coal Measures, as understood in other States, but to the Quinnimont group of Fontaine, which is equivalent to the Seral Conglomerate of Rogers.

No junction was made in the Wise county coal-field between the work done by Prof. Lesley and that done by the writer; a gap of five miles remains yet to be filled. But there is no reason to doubt that, for the most part, the beds described by Prof. Lesley belong to the Coal Measures, and not to the Quinnimont group; as, indeed, Prof. Lesley has suggested. His hesitation with reference to their exact position arose in measure from the coarseness of the Coal Measures sandstones, some of which are decidedly conglomerate.

The section observed on the headwaters of Powell river contains twenty-one coal beds, seen, varying in thickness from three inches to almost fifteen feet. No limestone was found in the section, aside from a few nodules, and those are ferruginous. The prevailing rock is sandstone, and the shales, a small part of the column, are almost invariably sandy. The sandstones vary from fine-grained to conglomerate, with pebbles rarely larger than a chestnut, and usually not larger than a pea. The thickness of the lower or productive portion is about 920 feet.

As the available coal occurs in what is equivalent to the Lower Productive Coal series of Pennsylvania, it might be supposed that valuable beds should be looked for in the upper part of the section, where the Upper Productive Coal series of Pennsylvania ought to be represented. It is not likely that any such beds will be found. The coal beds of the upper group lose their importance southwardly and southeastwardly, so that, for example, the *Pittsburgh bed*, which in south-western Pennsylvania attains to a thickness of from 9 to 12 feet, becomes thin and poor on the Kanawha river of West Virginia. The diminution in thickness and deterioration in quality is so regular along the line of nearly 200 miles, that there is every reason to believe that it continues southward until the bed becomes utterly worthless.

Some of the coal beds in this field are of decided excellence, showing barely one half of one per cent. of sulphur, and from .75 of one per cent. to less than 4 per cent. of ash. One large bed yields an excellent coking coal, which will prove of immense advantage in the development of the iron ores in south-west Virginia and north-west North Carolina.

The Quinnimont Group or Seral (Pottsville) Conglomerate.

This group was observed along Stone mountain from the Little Stone gap to beyond Pennington's gap, and Mr. Moore describes it as making

part of that ridge to beyond the Tennessee line. Its beds are thrown over at a high angle, varying from 80 to 90 degrees, and its area is not materially wider than the thickness of the group. The same group occurs also on the easterly portion of Powell mountain.

This group is not far from 1000 feet thick, and is made up of sandstones, shales and coal beds. The highest stratum is a sandstone, known as the "Bee rock," which is about 135 feet thick, and is a marked feature along the northerly side of Stone mountain from Little Stone to Pennington's gap. This bed is more or less conglomerate. The lowest bed, also, is conglomerate, and is about 45 feet thick. Sandstones and conglomerates prevail, and some of the latter are very coarse. Six coal beds were seen in Pennington's gap and a seventh was found on Powell mountain.

The coal beds are variable in thickness, and in the quality of their coal, so that none of them attains to real economic importance. Those in Stone mountain have suffered severe crushing, and are apt to be pockety. The best is that which immediately underlies the "Bee rock," and varies from one to three feet. The same bed is even more irregular on the southerly face of Powell mountain, where its thickness is from 2 to 14 inches. A second bed of workable thickness was seen in Powell mountain, but it is concealed in both Big Stone and Pennington's gaps. This, at not far from 350 feet below the top of the group, is from 2 to 3 feet thick, and seems to hold a place very nearly like that which is mined for coking at Quinnimont. In Powell mountain, however, the coal is sulphurous, and can be used only for domestic purposes.

The coal beds in the greater part of the Tennessee coal-field belong to this group, and, without doubt, much of the section obtained in the north-eastern district of that coal-field should be referred to the same horizon, as Prof. Safford has done. The coal beds there are somewhat variable. A noteworthy feature of this group in Tennessee is that the bottom plate of conglomerate is absent, and the Coal group passes directly into the Lower Carboniferous.

The Lower Carboniferous.

The two divisions of Lower Carboniferous recognized in Tennessee by Prof. Safford, and named by him the *Mountain Limestone* and *Silicious* groups, are fully represented here. These names are used in this memoir in preference to those now used in Pennsylvania, because in this region, the old division of Lower Carboniferous into Umbral and Vespertine or Nos. XI and X would place all the limestone together, and thereby do violence to the actual relations of the beds.

The beds of this series are well shown along Stone mountain; on the bluff of Powell mountain overlooking the valleys of North Fork of Clinch, and the South Fork of Powell river, and in Brushy mountain near the North Fork of Holston river.

The Mountain Limestone Group.

This group exhibits some surprising variations. Along Stone mountain, the section as shown in Pennington's gap is

1. Shales and sandstones, with some thin limestones.... 705′
2. Limestones and calcareous shales..... 150′

under which comes the massive limestone of the Silicious group. But in Brushy mountain, where the exposures are almost complete, the section is:

1. Shales and sandstones, with thin limestones..... 800′
2. Limestones and calcareous shales..... 1470′

No measurements were made on Powell mountain, but the thickness of the group is not materially different from that shown in the Stone mountain gaps. The succession is complete on the Holston, and the exposures are so good that there is not the slightest reason to suspect a fault; as, indeed, will be apparent to any one who will consult the detailed section given in the chapter on the Holston area. The shales and sandstones on top are more or less calcareous; some of the sandstones are almost sky-blue, and they break with an irregular fracture; others are calcareous grits, but there are some which are comparatively soft. Several beds are used for the manufacture of hones and grindstones. This part of the group is well shown in Pennington's gap, when the river is low. It is exposed also in the Wolf creek gorge, which is followed from Holston river by the Bristol Narrow Gauge Railroad.

The greater part of the lower division in Stone mountain consists of calcareous shale, there being comparatively little limestone; but in Brushy mountain, there is very little shale, and many of the limestone beds are remarkably free from foreign matter; chert occurs in small quantity in some of the lower beds both in Stone mountain and near the Holston.

Fossils characteristic of the *Chester* limestone occur plentifully in some beds at all localities. *Pentremites godonii, Productus semi-reticulatus* and an undetermined *Zaphrentis* were found in Hunter valley; *Productus semi-reticulatus, Hemipronites crassus, Spirifera leidyi, Athyris subquadrata, Cyrtoceras, Fenestella* and *Zaphrentis spinulifera* were obtained in Pennington's gap; in Brushy mountain the stems of crinoids and *Chonetes* are common in some of the shale beds of the upper part of the group. The higher limestones are made up mostly of a *Fenestella*, with occasionally a *Zaphrentis* or a *Productus;* while in the lower limestones crinoid stems, *Fenestella, Zaphrentis, Productus cora, Productus elegans, Spirifera leidyi, Athyris subquadrata, Pinna missouriensis?*, and *Allorisma* are very common, along with other forms not recognized during the hurried examination.

The Silicious Group.

In Tennessee, according to Prof. Safford's statement, this group is double, consisting of

1. The *Lithostrotion* or coral bed, a cherty limestone, fossiliferous and everywhere characterized by *Lithostrotion canadense.*

2. The Lower or Protean member, variable, mostly silico-calcareous; often limestone; often sky-blue; contains much chert in its middle and lower portions; sometimes beds of crinoidal limestones.

This division is easily recognized in middle Tennessee, but the distinction is not so clear in eastern Tennessee. "So far as its presentation in East Tennessee is concerned, no division is practicable."

Within the area under consideration, the group is double. It is shown in the gaps of Stone mountain and is well exposed near the North Fork of Holston river along the line of the Bristol Narrow Gauge Railway Company. The section at Pennington's gap is:

1. Cherty limestone..... 200′
2. Reddish silicious beds, some of them blue on fresh surface, some shale..... 150′

The lower member was identified by Mr. Moore, who has visited this gap, with the Protean member or the Knobstone of Kentucky. The limestone is well exposed both here and in Big Stone gap, and at both localities it contains much chert in nodules, sometimes as large as a melon. The change in this group is as striking as that observed in the Mountain Limestone group, and the section near the North Fork of Holston is as follows:

1. Limestone and shale..... 655′
2. Calcareous sandstone and shale..... 100′

Several of the limestone beds hold very much chert, in layers and nodules, but the quantity is comparatively small in the lower beds, one of which is almost free from it. The lower member of the group consists of sky-blue grits, breaking with irregular fracture, and some yellow shales in which is a carbonaceous layer. The exposure is not wholly complete and between 30 and 40 feet of the upper part of the shale is concealed. The top layers for about 10 feet are fairly well shown in the railroad side-cutting. A *coal bed* may belong in the concealed interval as *coal* is said to have been digged in the bed of the river almost directly opposite to this concealed space.

The only trace of fossils found in the lower member was a fragment of what seemed to be *Leiorhynchus;* no *Lithostrotion* was seen in the upper member, but *Productus* and *Athyris* are common, as are also crinoid stems and bryozoans. These may be collected either in Stone or in Brushy mountain. The chert often replaces *Productus.*

The Protean member of the Silicious group shows some interesting variations; Prof. Fontaine obtained the following section on the Greenbrier river of West Virginia:

1. An upper member consisting almost entirely of red marlites..... 250′
2. A middle member characterized by predominance of gray sandstones, containing *coal*..... 350′
3. A lower member, characterized by silicious sandstones and conglomerate. Thickness exposed, 60′. With this should probably be counted 500′ of underlying more silicious flags, total..... 560′

There is no room for doubting the identity of this section with the Protean group, for Prof. Fontaine obtained *Lithostrotion canadense* from the lime-

stone near Lewisburg, West Virginia. The red shales underlying the limestone unquestionably belong not with the limestone, but with the underlying shales and sandstones. In Brush mountain and its vicinity in Montgomery county, Prof. Fontaine found:

The upper member	1090′
The middle member	670′
The lower member	930′

In all 2690′ instead of 1160, as on the Greenbrier river. *Coal beds* occur in both sections. But when the line of the Bristol Railroad is reached in Brushy mountain very near the border line between Scott and Washington counties, this great mass has diminished to barely 100′, its *coals* have disappeared and there remains of it nothing but some shales and shaly sandstones, most of them more or less calcareous. In eastern Tennessee the distinction between the Protean and the Upper member is obscure, owing probably to increase of limestone in the lower member.

The Devonian.

This is represented by the Chemung and Hamilton. The Coniferous and Catskill are absent.

The full section of the Devonian was seen only in Brushy mountain and the Poor valley between that and Clinch mountain. The first ridge of Brushy mountain is composed of Devonian rocks, and very fair exposures of the series can be found along lines running from the foot of Clinch mountain through the numerous gaps in that ridge. The succession is

Chemung	300′
Hamilton	830′

But in the Poor valley of Stone mountain and along the face of Powell mountain, the Chemung and much of the Hamilton are wanting, so that the rocks of the Silicious group rest directly on the lower Hamilton shales.

The Chemung, as shown along Brushy mountain, between Moccasin gap of Clinch and the railroad bridge over North Fork of Holston, consists of irregularly bedded sandstones and shales, containing more or less of nodular clay iron-stone and some dark shale. Fossils are not very numerous, but two thin layers associated with conglomerate bands show characteristic Chemung species, *Spirifera disjuncta* and *Productella boydii*, along with *Chonetes* and other forms which could not be obtained in good enough condition for identification. *Spirophyton* occurs plentifully in the lower beds. These rocks are well exposed along the railroad excavations between Mendota and the Holston bridge.

The Hamilton is triple, dark shales on top, yellow sandy shales in the middle, and black, more or less carbonaceous shales below; thus showing the general divisions observed in New York and Pennsylvania. All three of the divisions were seen in the Poor valley and Brushy mountain; but in the vicinity of Stone mountain and of the North Fork of Clinch river, only the lower black shales were found. The thickness of these near Stone mountain is probably not more than 125 or 150 feet, while at one locality it

is certainly less. The lower shales are often very rich in carbonaceous matter and two beds near the base have been mistaken for *coal* beds. Iron pyrites occurs plentifully in these lower shales at all localities and alum incrustations are common. A fine-grained, nearly white sandstone is shown at several places near the base of the group; it is a good firestone and has been hauled nearly forty miles by wagon, for use as furnace lining.

Few fossils were seen in the Hamilton; a *Chonetes* occurs plentifully in the upper shales and imperfect specimens of *Lingula* were found in the lower shales. These Hamilton beds are the black shales described in Prof. Safford's report on Tennessee.

The Upper Silurian.

This is represented by the Oriskany, Lower Helderberg, Clinton and Medina; the Niagara and the Oneida Conglomerate were not recognized.

The Oriskany.

This is a sandstone, probably not more than 35 or 40 feet thick, which is shown in the Poor valley of Powell river, and along the valleys of Wildcat creek and the North Fork of Clinch; also along the latter stream at the foot of Powell mountain, and in the Hunter valley at Stony creek. It is absent along the southerly foot of Clinch mountain, where, indeed, the Upper Silurian is represented only by the Medina and a small part of the Lower Helderberg.

The Oriskany sandstone is coarse, reddish on exposed surface but white on the fresh surface. It is friable, and at some localities, notably along the North Fork of Clinch river, it readily disintegrates on exposure. Very possibly the upper ore-horizon along Wildcat creek and the North Fork of Clinch river may belong in part to this sandstone. This rock contains *Streptorhynchus hipparionyx* on Stony creek; in the Poor valley of Powell river, it contains *Merista lata*, but with that there occur some forms belonging to the Lower Helderberg, so that in the writer's previous memoir the sandstone was referred to the lower group. The relation between the two groups is very close throughout this region.

The Lower Helderberg.

This group accompanies the Oriskany. In a general way its characteristics are very similar to those of the same group in New York. The *Leperditia* bed at the base is shown near Big Stone gap. Below this is a coarse sandstone like the Oriskany, which is shown at some localities along Powell river, and is well exposed along the line of the Pattonsville fault. The group closes with a limestone, which frequently becomes silicious. It is occasionally fossiliferous and the species are very characteristic.

The lower sandstone of this group is ferriferous and occasionally holds a brown hematite of excellent quality. A fossiliferous brown hematite was seen at the southerly foot of Clinch mountain, which, in all probability, should be referred to this group.

The Clinton.

Prof. Safford has found in Tennessee above the Clinton group a limestone, which he regards as representing the Niagara group of New York; but no traces of that limestone were observed by the writer, unless the fragments seen on the Jonesville and Gladesville pike and belonging in the concealed interval between rocks of Clinton, and those of Lower Helderberg age, may be referred to it. Elsewhere no bed was seen which could be regarded as representing the Niagara group.

The Clinton group is present in Poor Valley ridge; on both Wallen's ridge and Powell mountain; and at two localities along the northerly side of Buckner's ridge; but it is absent from the southerly side of Clinch mountain. The structure of that ridge is shown in Moccasin gap, where the Medina sandstone underlies the Lower Helderberg, on which the Hamilton shales rest.

No full section of the Clinton group was obtained, but its thickness cannot be far from 700 feet. The rocks are sandstones and sandy shales, but a calcareous sandstone, 60 feet thick, and containing thin bands of very fair limestone, occurs near the middle of the group. Three beds of the fossiliferous ore were seen, and, according to Mr. Pennington, who owns the forge in the gap which bears his name, two others exist, but they are very thin. The three beds belong below the middle of the group. The lower two are not far from 50 feet apart, but the interval to the upper bed is somewhat greater. These intervals show considerable variation in Poor Valley ridge, where the ore has been opened at several localities. Two beds were seen on the southerly slope of Wallen's ridge and three on Powell mountain; while only two are exposed in Hunter valley. The most important bed is the middle one, which usually carries excellent ore. The others vary much in thickness and quality of the ore.

The Medina Sandstone.

This is a salient feature of the region, as it forms the crest line of Wallen's ridge, Powell mountain and Clinch mountain. For the most part, it is a massive, fine-grained and very hard sandstone, but it has some layers of conglomerate, which are most numerous near the top. On Clinch mountain it is divided by bands of shale in which brown hematite occurs. On Powell mountain and Wallen's ridge it graduates upward into a reddish sandstone which may represent the white oak sandstone of Prof. Safford's report, though the writer is inclined to regard it as part of the Clinton or dyestone group, the total thickness as observed on the several ridges does not exceed 400 feet. No fossils were seen other than casts of the characteristic fucoid.

THE LOWER SILURIAN.

This is represented by Formations II and III of the Virginia column. A more convenient division for description is that made by Prof. Safford into the Knox and the Trenton and Nashville groups. The Knox group in-

cludes all but the upper part of No. II, or the Chazy of New York, which is placed by Prof. Safford in his higher group.

These groups are exposed over a great part of the area; they are the surface rocks in the great Powell valley between Poor Valley ridge and Wallen's ridge; they are shown in the southerly side of Wallen valley and the northerly side of Powell mountain; they extend unbroken from the Hunter Valley fault to the crest of Clinch mountain; and again from Holston fault to the Valley of Virginia. Detailed study of these groups could not be made; they are faulted and folded in the most perplexing manner, so that in the course of a day's ride across the country one passes again and again over the outcrop of the same beds. But the general features of the higher group and the upper part of the lower can be worked out somewhat rapidly in Moccasin ridge, where the dip is apparently unbroken by a fault. The lower parts of the Knox group are shown in Buckner's ridge.

The Trenton and Nashville Group.

This embraces the Hudson, Trenton and Chazy groups of New York. It is well shown in Powell valley, in Wallen's valley, and on the southerly slopes of Copper and Moccasin ridges. A section was obtained in the vicinity of Estillville, Scott county, which is:

1. Shales with thin limestone, calcareous at base..... 755′
2. Limestones and shales..... 430′

thus giving a thickness of 1185 feet for the series. A detailed description is given in the chapter on the area drained by Clinch river. The thickness of the shales is nearly the same on the northerly side of Wallen's ridge, where they are well exposed. They are black and more or less fissile at the base, but higher up the color becomes brownish to reddish brown, and the rock is in thick layers. The change to the Medina sandstone is well shown on the crest of Powell mountain, where it is abrupt. A great limestone lies at the base of the group; it is massive, occurs in beds from 10 to 20 feet thick, which are separated by thinner beds of shale. Many of these limestone beds yield a beautiful marble, which is equal to any from the typical localities in Tennessee.

Fossils are abundant in many parts of the section.

The Knox Group.

As in Tennessee, this group is triple; the upper division, consisting of cherty limestones and dolomites, is well exposed in Moccasin and Copper ridges, the middle or shaly division and the lower, consisting of calcareous sandstones, are shown in Buckner's ridge and near Clinch river.

The section of the upper division, as obtained in Moccasin ridge, may not be complete, part of it having been obtained on one road and part of it on another; there may be a gap of nearly 300 feet. The estimated thickness is about 1750 feet. In the upper half the limestones are more or less dolomitic and contain much chert, so much, that in three great beds the chert predominates. These beds are ridge making, and they crown the summits

of the several subordinate ridges in both Copper and Moccasin ridges. Those cherty beds, too, are iron bearing, and each of them carries extensive deposits of brown hematite, some of which have been explored. The lowest bed of this division is a calcareous sandstone very similar to that at the base of the group.

The middle division consists mostly of shales, with which are beds of impure limestone, more or less silicious and varying from 2 to 10 feet in thickness. This is shown along Clinch river at many places as well as along Stock creek and along the Jonesville and Estillville road as it passes from the North Fork of Clinch river to the mouth of Stock creek.

The lower division is a mass of calcareous sandstone and sandy limestones with some shale, the whole containing great quantities of iron pyrites, which makes up fully one-fifth of the whole mass of some beds. This mineral occurs in irregular laminæ often one-fourth of an inch thick, which sometimes make a network on the exposed surface of the rock. This division is well exposed along the whole line of the Hunter Valley or Clinch uplift within the region examined.

The composition of the Knox group here is approximately as follows:

1. Limestones, shales and chert beds ..... 1750′
2. Shales and limestones ..... 1600′
3. Calcareous sandstones, pyriferous ..... 500′

Thus giving for the whole group a thickness of not far from 3250 feet.

III. Geology of the Area Drained by Powell River.

The important coal-field lying north from Stone mountain narrows rapidly westward owing to the convergence of Stone and Black mountains, so that, as far as Virginia is concerned, it practically disappears at but a little way beyond Pennington's gap. But the available area diminishes even more rapidly. The streams flowing from Black mountain become shorter, and have a greater fall, so that, as the beds dip toward Black mountain, the area above natural drainage is much smaller even proportionately on the waters of the North Fork of Powell than it is along those forks which unite at the head of Big Stone gap.

The previous memoir by the writer contained a section of the *Coal Measures* as they appear above Big Stone gap; but the lower part was given according to a rude estimate, while 500 feet at the top had not been examined in detail. As already intimated, the unexamined part at the top is much greater than is given in that section. As amended, according to observations at the head of Pennington's gap and according to Mr. Moore's barometric determination of the height of Black mountain at the head of Looney branch of Cumberland river, the section is:

1. Not examined ..... 800′
2. Sandstone and sandy shale ..... 200′
3. *Coal bed* ..... 0′ 4″
4. Sandstone ..... 30′
5. *Coal bed* ..... 1′ 5″
6. Sandstone and shale ..... 115′

7.	*Coal bed*	0′ 6″
8.	Sandstone	70′
9.	*Coal bed*	2′
10.	Fireclay with stigmaria	2′
11.	Sandstone	12′
12.	*Coal bed*	1′
13.	Sandstone	70′
14.	Shale	20′
15.	*Coal bed*	0′ 4″
16.	Sandstone	26′
17.	Shale	4′
18.	*Coal bed*	0′ 10″
19.	Ill-exposed, mostly sandstone	65′
20.	*Coal bed "Cannel seam"*	7′ 3″
21.	Sandstone	50′
22.	*Coal bed—Upper Splint*	3′ 6″
23.	Sandstone	70′
24.	*Coal bed—Lower Splint*	3′ 6″ to 4′ 6″
25.	Ill-exposed, mostly sandstone, some yellow shale	120′
26.	*Coal bed*	Blossom.
27.	Sandstone	70′
28.	*Coal bed*	1′
29.	Shale and sandstone	25′
30.	*Coal bed—Kelly seam*	2″ to 15′
31.	Sandstone	45′
32.	Shale	5′
33.	*Coal bed—Imboden seam*	8′
34.	Shale	6′
35.	Sandstone	35′
36.	Carbonaceous shale	0′ 4″
37.	Sandstone	70′
38.	*Coal bed*	1′ 6″
39.	Ill-exposed, mostly shale or shaly sandstone	60′
40.	*Coal bed*	18″ to 3′
41.	Sandstone	35′
42.	*Coal bed*	2′
43.	Sandstone	60′
44.	*Coal bed*	2′ to 3′
45.	Sandstone and some shale	80′
46.	*Coal bed*	3′
47.	Shale and sandstone	85′
48.	*Coal bed*, blossom seen, said to be	1′ 6″
49.	Interval concealed	125′
50.	*Coal bed*, not seen, said to be	2′
51.	Shale	25′
52.	"Bee rock" of Quinnimont group	
	Total thickness	2348′

As the important beds of this group were described in detail in the previous memoir, only a brief synopsis is necessary here. No additional information has been obtained respecting them, for the area drained through Pennington's gap by the North Fork of Powell river is wholly undeveloped, and only the lower coal beds are well exposed.

The *Cannel* seam consists of:

Cannel	2′	
Alternating layer of *coal* and shale	1′ 10″	7′ 3″
Bituminous *coal*	3′ 5″	

But the bed is variable and at another locality it shows three layers of *coal*, amounting in all to but 2 feet, distributed through 19 feet of measures. The *coal* from the *Upper Splint* is of superior excellence, containing but 3.075 per cent. of ash and but 0.406 of sulphur; the coal from the *Lower Splint* seems to be of equally good quality. The *Kelly* seam is a variable bed, which, where thickest, shows three divisions; the upper one is slaty, the lower one is a splint of fair quality, while the middle division seems to be a gas coal of remarkable excellence, as it contains 38.850 of volatile combustible matter, with 0.771 of sulphur and only 0.890 of ash.

The *Imboden* or coking seam is by far the most important. It was first traced by General J. D. Imboden, who made many prospecting pits in it to determine its value. This bed varies in thickness from 6′ 11″ to 8′ 5″, and everywhere yields a soft coal, which produces an excellent coke. The coal contains but 1.515 of ash and only 0.594 of sulphur.

Nos. 38 and 40 were seen only in Pennington's gap. The former is insignificant; the latter is badly distorted by pressure and the coal is so crushed as to be useless. The whole section from No. 37 to the bottom is vertical at the head of Pennington's gap. The coal bed, No. 42, has not been mined, but it is exposed in the bank of the North Fork, where it shows a clay parting midway. No. 46 is evidently the same with No. 44 of the section on p. 91 of the previous memoir. It shows nearly 3 feet of good coal on the North Fork, where some mining has been done. The coal is fat, caking and contains much mineral charcoal. The two beds, Nos. 49 and 51, were reached only in Pennington's gap, where they are no longer exposed.

Stone Mountain.

The structure of this mountain has been explained in another part of this memoir. The groups involved in the fold include the whole series from the Clinton up, but in the mountain as it now stands, one finds only the lower part of the Coal Measures, with the Quinnimont group and Lower Carboniferous. Exposures are very poor in both Little and Big Stone gaps, and the succession of the rocks could not be made out until Pennington's gap was reached. There the following section of the Quinnimont group was obtained, the thicknesses being estimated:

1. Sandstone "Bee rock,".....135′
2. Shale..... 15′
3. Sandstone..... 12′

4.	*Coal bed*	1′ 2″ to 3′
5.	Sandstone	20′
6.	*Coal bed* and shale	1′
7.	Sandstone	200′
8.	Conglomerate	100′
9.	Concealed	60′
10.	Sandstone	45′
11.	*Coal bed*	0′ 6″
12.	Shale, clay and sandstone	40′
13.	Flaggy sandstone	15′
14.	Massive sandstone	120′
15.	Concealed	45′
16.	*Coal bed* with much shale	5′
17.	Imperfectly exposed, much conglomerate	95′
18.	*Coal bed* and shale	1′ 8″
19.	Shale	20′
20.	*Coal bed* and shale	2′
21.	Clay	7′
22.	Sandstone	15′
23.	Pots of *coal* in sandstone	7′
24.	Conglomerate	45′
	Total	1009′ 2″

The rocks are vertical; but the gorge is very crooked and some difficulty was encountered in the effort to estimate the thickness of No. 7, which may be somewhat greater than is given above.

No. 1, the "Bee Rock" of Big Stone gap, forms a conspicuous comb along Stone mountain from Little Stone gap to certainly 3 miles west from Pennington's gap, and it is well shown at the head of each gap. The upper part is flaggy and rather fine-grained; but below, the rock becomes massive and coarser, with numerous pebbles. No bedding is perceptible for 65 feet from the bottom. Some plant impressions were seen and there is much carbonized wood in large fragments. The shales underlying this rock are brown to reddish brown, clayey and without distinct bedding. The sandstone, No. 3, is blue and flaggy in the upper part, but becomes gray and shaly below.

The *Coal bed*, No. 4, is much crushed and its thickness has been much reduced by the violent pressure. It is badly twisted and is from 14 inches to 3 feet thick. The coal is good, caking, admirable for blacksmiths' use and contains much mineral charcoal. The underlying sandstone is argillaceous and near the coal it is really a sandy fireclay containing many stems and rootlets of *Stigmaria*. The little *Coal bed*, No. 6, is but 5 inches thick and has black shale both above and below it.

No full exposure of the sandstone, No. 7, could be found. The mass varies from fine-grained sandstone to coarse conglomerate and holds some bands of shale. A *Coal bed* is said to occur in this interval, but no traces of it were seen. Nos. 8 and 10 are conglomerate. The latter crosses the

river at Pennington's mill and is well exposed immediately below the dam. It is light gray, cross-bedded and contains many rude impressions of plant stems. Some of its finer layers yield a good firestone; and the lining of Pennington's forge, constructed of this sandstone, has stood for three years. This is said to bear a dash of cold water without cracking, even when at a bright red heat. The little *Coal bed*, No. 11, is of no value, but the clay underneath it makes excellent brick though it is too ferruginous to be used for firebrick. No. 13 is shown immediately below the forge and some of its layers do well as firestone. Much coarse conglomerate occurs in Nos. 14 and 17, and there are several coarse layers in No. 24. Many impressions of plant stems were seen in No. 22.

The *Coal beds*, Nos. 16, 18 and 20, are no longer exposed in the gap. They were opened by Mr. Pennington, but proved worthless. No. 16 was opened both in the bank of the stream and on the hillside; it is 5 feet thick at both places, but the *coal* and shale are in nearly equal proportion and are so mixed that the bed is without value. A bed, shown on the ridge at about two and one-half miles from gap, is supposed by Mr. Pennington to be the same with No. 16. It is 2 feet 9 inches thick and yields good coal, of which some has been hauled to Jonesville.

The other beds consist only of a worthless commingling of *coal* and shale. No. 23 may have been a *Coal bed* at one time, but if so, it was torn up and re-distributed during the formation of the overlying sandstone, for now it consists of simply small pockets of pulverized coal scattered through 7 feet of sandstone.

The massive beds of this group project above the surface like dikes and some of them overhang the river.

The Lower Carboniferous limestone is well exposed at many places along Stone mountain, but continuous exposures were found only in Pennington's gap, where the following succession was made out, the thicknesses being estimated:

Mountain Limestone Group.

1.	Imperfectly exposed	40′
2.	Sandstone	15′
3.	Dark fissile shale	5′
4.	Sandstone	20′
5.	Imperfectly exposed, much shale	200′
6.	Sandstone	75′
7.	Shale with thin limestone	35′
8.	Sandstone	40′
9.	Concealed	60′
10.	Calcareous sandstone	120′
11.	Dark fissile shale	5′
12.	Calcareous shale	90′
13.	Argillaceous limestone, fossiliferous	15′
14.	Imperfectly exposed	60′
15.	Massive limestone	25′
16.	Calcareous shale, fossiliferous	50′

Silicious Group.

17. Limestone.....200′
18. Shale and sandstone.....150′

Total Mountain Limestone group, 855′; Silicious group, 350′.

The interval, No 1, is filled for the most part with shale, though there are traces of sandstone and a bed of rather lean carbonate of iron. The latter has been opened by Mr. Pennington, but it is too lean for use in his forge. The shale, No. 3, is quite rich in carbonaceous matter and it may represent the *Coal beds* of south-west Pennsylvania, belonging at this horizon. Nos. 2 and 4 are hard red grits. The interval, No. 5, contains some red shale, some bluish grit-like beds, but for the most part it is effectually concealed. The sandstone, No. 6, is fine-grained, mostly light colored, and the sand is sharp and cleaned. The bed is well exposed on both sides of Pennington's gap and is the first sandstone bed seen in ascending Big Stone gap. It is the principal source of the sand covering the "bottom" of Powell river and that of the North Fork near the gaps. No. 10 is a hard blue grit, containing not a little oxide of iron, which causes disintegration on exposure. It is well shown in the bed of the North Fork in Pennington's gap. No. 14 is imperfectly exposed, but here and there it shows some limestone and red shale. Mr. Pennington says that some good iron ore has been obtained from this interval. No. 15 is an excellent limestone, and it would be good either for furnace use or in the manufacture of lime. Chert first appears in the lower part of No. 16, where numerous layers were seen from half an inch to two inches thick and richly fossiliferous. From one of these the following species were obtained during a hurried examination: *Fenestella; Zaphrentis spinulifera; Productus semi-recticulatus; Hemipronites crassus; Spirifera leidyi;* and *Athyris subquadrata.*

The great limestone, No. 17, is well shown along the southerly face of Stone mountain from Little Stone gap to far beyond Pennington's gap; and it is well exposed in each of the gaps. The rock is mostly fine-grained and compact, with conchoidal fracture, though here and there a layer occurs which is somewhat granular. Some beds contain much chert in nodules occasionally as large as an orange. Fossils are numerous, but for the most part they cannot be obtained in identifiable condition. *Productus cora* with an unrecognized *Zaphrentis* was obtained near the mouth of Big Stone gap.

No. 18 has been identified by Mr. Moore with the Protean member of the Silicious group of Tennessee, the Knobstone of the old Kentucky reports. It is not very well exposed at any locality visited; but as far as seen, it consists of bluish sandstones, weathering reddish, with some shale. These sandstones are slightly calcareous and some of them are true grits. No fossils were seen in this stratum.

Poor Valley and Poor Valley Ridge.

Under this head may be included not only that narrow area between Stone mountain and the fault of Poor Valley ridge, but also the area

around the headwaters of the South Fork of Powell river and its tributary, Wildcat creek. This embraces so much of the region between Stone mountain and Powell mountain as is drained by those streams.

At the apex of this space, where Stone and Powell mountains come together, just east from Little Stone gap, one finds in the valley only the Hamilton shales. The gentle anticlinal, in which the fault of Poor Valley ridge originates, soon brings up the Oriskany, the Lower Helderberg, and, at a little way further west, the Clinton ore group. The ridge formed by the anticlinal and gradually developing fault is known here as Wallen's ridge and shows the Clinton group on both sides, with the higher groups at a little distance from the foot. No detailed section was made on Powell mountain, but the Hamilton shales are at its base; higher up is the Lower Carboniferous, forming a conspicuous band along the face of the mountain; while above it the Quinnimont group extends to the crest, whence it may be followed to the Hunter valley.

Along Wildcat valley and the southerly slope of Wallen's ridge, Upper Silurian rocks prevail, the Medina at the crest of the ridge, the Clinton lower down the slope, while the Lower Helderberg occupies the valley and here and there reaches some way up the side of the ridge. The Clinton ores are unusually good here, that from one bed showing 52.6 per cent. of iron with but 0.116 per cent. of phosphorus.* The Lower Helderberg shows two ore-horizons, of which the upper may belong in part to the Oriskany. The lower horizon has an unusually good brown hematite, with 52.55 per cent. of iron and only 0.051 per cent. of phosphorus. The pockets of good ore are separated by stretches of varying length, in which an enormous amount of brown hematite is seen, but so mixed with sand as to be altogether unavailable. Beyond all doubt the higher horizon carries much good ore, but the old workings, whence ore was obtained for a Catalan forge, have been filled up and only the silicious ore is exposed.

The Helderberg ores of Poor valley are of uncertain value. Some fair ore occurs at several miles east from Big Stone gap, but the most of that seen there is silicious and evidently belongs to the higher horizon. It contains many fossils characteristic of the Lower Helderberg. Further west, the ore seems to be wanting, no evidence of its presence having been observed at any exposure between Big Stone and Pennington's gap.

The best exposure of the Hamilton shales in the Poor valley is at a mile or so east from the Big Stone gap, where the rock seems to be thicker than it is further west. It is said to yield fossils there. The increasing strength of the disturbance westward makes the dip of these beds vertical before reaching Pennington's gap and exposures in that vicinity are not wholly satisfactory. The valley itself is very narrow until beyond that gap, where it opens up somewhat. No trace of Chemung rocks were found in the valley and the Lower Carboniferous rests directly on the lower black shales of the Hamilton.

*All analyses in this memoir, unless otherwise stated, are by Mr. A. S. McCreath, chemist to the Second Geological Survey of Pennsylvania.

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No good section of the Clinton was obtained; the partial one obtained near Big Stone gap and given in the previous memoir contains all the details yet secured. The ores of this group are easily followed along the valley and ridge. Three beds occur not far from Big Stone gap, but only one of them is really important. This, as exposed on the Horton property at say a mile and a half from the gap, shows:

Hard ore	4′ 8″
Soft ore	2′ 6″

The lower part of the upper layer for, say 20 inches, is a very fair ore, though inferior to that from the lower portion of the bed. This is the middle bed. The upper bed is shown in the bank of Powell river not far from the gap, where it is from 5 to 8 inches thick; while the lower bed, as shown in Cedar gap, through Poor Valley ridge, contains little soft ore. The same beds are shown in the gap of Powell river through Poor Valley ridge and some of the ore from that locality has been reduced in Mr. Pennington's forge, where it proved good. Mr. Pennington has opened three beds of ore near his gap, but of these only the middle one is good. This shows:

Soft ore	4″
Clay	8″
Soft ore	25″

The clay is irregular and is said to disappear, so that the ore is sometimes fully 3 feet thick. The upper layer at this exposure is pebbly and the lower layer is equally so for an inch or two at the top; but Mr. Pennington states that this is an abnormal condition and that the pebbles are rarely present. This ore is mined to supply Pennington's forge at which about 200 pounds of excellent iron are made daily.

Powell Valley.

Throughout this valley, which embraces the whole space between Poor Valley ridge and Wallen's ridge, one finds only formations II and III. The distinction between the groups was not made out in detail, for the structure is too involved to be worked in a reconnaissance. It is altogether probable that the magnesian beds of the Knox group occupy the northern side of the valley in the wider parts of the area. They lie close to the fault in the Turkey cove, while, nearer Wallen's ridge, the beds of the higher group are well shown and yield great numbers of characteristic fossils. Good localities for collectors were seen along the road crossing Wallen's ridge from Turkey cove, and along the Jonesville and Gladesville road in the cove. The magnesian limestones on Elk Knob are practically horizontal and weather into detached blocks and pillars, making the long summit of that hill a "rock city." Brown hematite of excellent quality is said to exist on Chestnut ridge in this valley; and some of it has been tried with good results at Pennington's forge.

Wallen's Ridge and Valley.

At Turkey cove, the limestones of III rise high up on the side of Wallen's ridge, but the shales belonging at the top of the group are concealed along the road crossing the ridge. Further west, however, as the ridge is pushed away toward the south-east, the limestones reach only to its foot or to but a little way up its side. The shales are well shown along the Jonesville and Estillville road as it winds up the mountain. They are dark and fissile below but become somewhat sandy above. Thin irregular bands of limestone occur, all of which are fossiliferous. The thickness of the shales is not far from 700 feet.

The Medina sandstone is reached at the summit of the ridge, where, for the most part, it is fine grained and compact; but it contains some layers of shale and an occasional bed of conglomerate. Exposures are incomplete near the road, but the rock forms cliffs at two or three miles further east. The thickness, as estimated, is not far from 350 feet. The Clinton group is reached on the southerly side, where it is not well exposed. The fossil ores are shown at several places, but are best seen near the head of the valley, where Mr. Jerome Duft has explored them to a slight extent. The Lower Helderberg rocks are mostly concealed.

The Wallen Valley fault passes very near the southerly foot of Wallen's ridge, and is crossed by the Jonesville road at perhaps three-fourths of a mile from Wallen's creek. The exposures near the line of fault are very poor, but they suffice to show that the beds in contact with those of the Lower Helderberg belong near the top of the Knox group, for the soil has a deep red color and fragments of chert are scattered through it. The first satisfactory exposures are those of the Trenton and Nashville group, whose beds are well shown at Stickleyville and elsewhere along Wallen's creek. They are very fossiliferous, though the number of species found at Stickleyville is small. The following were seen:

Stromatopora; Chætetes petropolitana; Bryozoans; Strophomena alternata; Leptæna sericea; Orthis testudinaria; Orthis occidentalis; Orthis tricenaria?. The *Chætetes* is often replaced by chert, as is also the case on the northerly side of Elk Knob in Powell valley.

The limestones of this group continue nearly half way up Powell mountain, and, thence to the summit, the shales of the group are occasionally shown. The Medina sandstone is reached at the summit, where one looks down into the area drained by Clinch river.

As the Wallen valley fault disappears north-eastward, the outcroppings of Upper Silurian on the southerly slopes of Wallen's ridge and Powell mountain approach each other; and on the easterly face of the divide between Wallen's creek and the North Fork of Clinch, the two outcrops seem to have come together, as do the similar outcrops on Wallen's and Poor Valley ridges, where the fault of the latter dies out. No detailed examination of this divide was made, and the structure was ascertained only in so far as was possible in passing through Slemp's gap.

IV. Geology of the Area Drained by Clinch River.

The whole of this area lies within Scott county. For convenience of description, it may be regarded as divided by the road leading from Big Stone gap to the mouth of Stock creek. The easterly division extends from the crest of Powell mountain to that of Moccasin ridge, and is drained by several streams, to which reference will be made in their place; the other division extends westwardly to the Tennessee line and southwardly from the crest of Powell mountain to Clinch river. It is drained principally by Little Stock creek and the North Fork of Clinch river.

The Western Division.

The Medina sandstone is somewhat imperfectly exposed on the summit of Powell mountain along the Jonesville and Estillville road, but appears in cliffs at but a little way further east. Its junction with the shales of Formation III is well shown at the roadside, and is very sharp, there being no transition bed. The Medina, for 35 feet from the base, is massive, cross-bedded, and not at all conglomerate, though here and there a pebble appears. Impressions of *Arthrophycus*, though not abundant, are by no means rare. Some imperfect exposures of Clinton rocks were seen at about one-third of the way down the mountain slope and numerous fragments of fossiliferous ore lie scattered in the road and on the hillside. Only one bed, however, was found in place, and its ore is highly silicious. Further east along this slope of the mountain, three beds have been exposed on property lately belonging to the Kane estate, which are equivalent to the three beds seen in the Poor Valley ridge. The upper one is very thin, and its ore is silicious, but the middle and lower beds are of workable thickness and their ore is good, though evidently somewhat leaner than that from the middle bed of the Poor Valley ridge.

These ores extend along the mountain face quite to the head of the North Fork of Clinch river, whence they cross the divide and continue along the southerly face of Wallen's ridge along Wildcat valley; but no measurement of the group or of its ores was made in Slemp's gap or above it along the North Fork of Clinch.

Still further down the slope or very near the foot of the mountain are the Lower Helderberg and the Oriskany, beyond which come the shales of the Hamilton. A small tributary to the North Fork of Clinch flows along the foot of the mountain, and the road to Sneedville follows it. These rocks are exposed along this stream, and the shales are reached at Robinson's mill, where they are dipping almost southward at a high angle. At a little way below the mill, the stream enters a gap through a low ridge produced by the Pattonsville fault, and on the other side it joins the North Fork. At the entrance to the gap, one reaches the coarse sandstone, and the limestone at the base of the Lower Helderberg, both of which have been pushed to 5 degrees beyond perpendicular. Several exposures of Lower Helderberg rocks occur within this gap, but the section is not continuous.

On emerging from the gap made through this low ridge, the stream enters the North Fork, which there changes its course, and for a short distance flows irregularly along the strike. The road follows the right bank of the stream, and winds so as to be now in the Lower Helderberg, then in the Hamilton shales. The upper limestone of the Lower Helderberg is well exposed at the roadside, not far below the gap, where it underlies the Oriskany, which is ferriferous. The river changes its course near Mr. James Robinet's place, and breaks across the Hunter Valley fault (Clinch River uplift), whose course is marked by Buckner's ridge. The Hamilton shales are fairly well exposed here and are dark throughout. Those resting on the Oriskany are richly carbonaceous, and films of *coal* are common in one layer, which is nearly 18 inches thick.

No rocks newer than the Hamilton shales are shown between the crest of Powell mountain and Buckner's ridge, as far, at least, as two miles west from the North Fork gap in the latter ridge. If the Pattonsville fault were absent, there would be ample room for the Lower Carboniferous groups, which, indeed, are present on Powell mountain in the other division of this area. A material change in the character of this fault must take place at not far from the gap, for Prof. Safford's map shows that the Lower Carboniferous groups are present at the State line both on the slope of Powell mountain, and on the ridge marked by the Pattonsville fault.

The gap of North Fork of Clinch exhibits the complicated structure of the Hunter Valley fault or Clinch River uplift. The pyritous calcareous sandstones, belonging to the base of the Knox group, form a bold ridge with the rocks dipping southward at almost 50 degrees; but at the base of the cliff on the northerly side, a considerable mass of limestones, reddish and white sandstones was seen. This is not less than 150 feet thick. Behind it is an imperfectly exposed interval between the base of this bluff and the last exposure of Hamilton shale, in which are fragments of sandstone not unlike the Oriskany. This mass is covered with débris and the succession of its beds could not be made out. Unsuccessful search was made for fossils. A conglomerate of rounded quartz pebbles bound by red hematite occurs here, and bears much resemblance to the Clinton ore; with it is a ferruginous sandstone, which, when casually examined, appears to be an iron ore. It is, however, merely a very fine-grained ferruginous sandstone. This is shown on both sides of the gap, and the apparent amount of ore is very great. But the material is utterly worthless as appears from Mr. McCreath's analyses; No. 1 being the conglomerate, and No. 2 the ferruginous sandstone.

Metallic iron	12.050	11.550
Sulphur	0.052	——
Phosphorus	0.862	——
Insoluble residue	69.400	——

This was worked many years ago in a forge, whose ruins still remain in the gap.

Returning now to the Jonesville and Estillville road, one finds the Lower

Helderberg, Oriskany and Hamilton as at Robinson's mill on the Sneedville road, and the little village of Pattonsville stands on the Hamilton; but the Pattonsville fault is crossed by that road immediately beyond the village and the Lower Helderberg is brought up as in the gap below Robinson's mill. The Oriskany sandstone is reached again near the "bottom" of North Fork of Clinch and varies in color from rusty yellow to dingy white. The rock is very friable and it must be somewhat calcareous, as the surface has given way at many places, showing the presence of caverns beneath. The hills are covered with loose reddish yellow sand, derived from this rock. Both the Lower Helderberg and the Oriskany sandstones are fossiliferous but the fossils are very obscure. Brown hematite occurs on the Pattonsville ridge and is continuous up the North Fork of Clinch. No analyses of this ore have been made, but the quality seems to be good. The Hamilton shales are continuous to the wall of Powell mountain in the other division of this area and are fairly well exposed at many places. Here, as at many other localities, they are supposed to hold *coal*.

Ascending the North Fork one reaches the strip of Lower Helderberg rocks in Slemp's gap near Ward's mill, and the upper limestone of that group is well shown at but a little way above the mill. These rocks remain in sight on both sides of the road until the summit between Clinch and Powell is reached. The Oriskany was not seen here, its place being concealed.

Returning again to the Jonesville and Estillville road, one crosses the Hunter Valley fault and enters Buckner's ridge at probably 2 miles from Pattonsville. An ill-exposed space of about 10 yards exists here, but there seems to be no reason to suppose that any rock lower than the Hamilton shale is brought to the surface. The Robinet "ores" are clearly absent.

In Buckner's ridge the calcareous sandstones and silicious limestones at the base of the Knox group have a dip of 45 degrees, which soon decreases to 30 degrees. With these are thin beds of shale, and the whole thickness is not far from 500 feet. Above this series are shales with irregular beds of impure limestone, in all about 1000 feet thick. These are followed by massive limestone, some of it dolomite, which extends beyond the divide and appears on the waters of Little Stock creek. The exposures are indistinct beyond this divide, until at some distance one comes to shales which bear close resemblance to those which rest on the calcareous sandstones. These shales are well shown along Little Stock creek, which flows between them and the massive magnesian limestones. The shales are badly twisted. The creek flows through a tunnel in the limestone, which is not far from 600 feet long, and from 10 to 15 feet high.

Few observations were made in Big ridge, the continuation of Copper ridge beyond Clinch river. The rocks are the same as those seen in Copper ridge and it is altogether probable that the reports respecting the occurrence of iron and manganese ores are true. One may not do more than to assert the mere occurrence of these ores, as nothing has been done to determine the extent of the deposits.

The Eastern Division.

The gradual disappearance eastward of the Pattonsville and Wallen Valley faults has permitted the retention of much newer rocks on the eastern than on the western part of Powell mountain: so that on the former the Quinnimont group and not the Medina sandstone forms the crest of the ridge.

Powell mountain has an abrupt slope on the north-westerly side, and the face toward Slemp's gap is so steep that it can be climbed only with great difficulty. The succession of the rocks on these bluffs is distinct, the Quinnimont group forming the rim, with the Lower Carboniferous, the Devonian and the higher beds of the Silurian in order below it. No detailed section was made here, but the Chemung, if present, must be extremely thin, and the probabilities are altogether in favor of the conclusion that it is wholly wanting.

The Hamilton shales are well shown on the road following the foot of Powell mountain and they contain carbonaceous bands in which thin streaks of *coal* occasionally occur. One of these was seen at barely half a mile below Ward's mill. The Lower Carboniferous rocks make a well-defined band, curving round the end of the ridge in Slemp's gap and continuing to immediately beyond Powder Mill gap, terminating where the Hunter Valley road leaves the line of railroad. The Mountain Limestone group is exposed near the school-house not far from the railroad, where it contains *Pentremites godonii, Zaphrentis, Productus semi-reticulatus,* and *Chonetes.* The Hamilton shale is shown between it and the calcareous sandstone of the Knox group, turned up by the Hunter Valley fault or Clinch River uplift. No traces of any lower rocks were observed between the limestone and the line of fault.

The rocks of the Knox group form a sharp, though low ridge, which is continuous into Russell county. The Hunter Valley road lies behind the ridge and soon rises upon the Quinnimont rocks, which seem to be in contact with the beds on the opposite side of the fault. This, probably, is not the case, but the coat of débris between the last definite exposures of the conglomerate and the base of the sandstone wall is so thick as to conceal everything.

Coal blossoms have been seen in all the hollows leading from the northern side of Hunter valley into Powell mountain. Some *coal* has been obtained along the Laurel Fork of Stock creek, at probably two-thirds of a mile from the valley, but the gorge is so close and rugged, that the coal can be brought down only by packing it on men's shoulders. In a bed which has been opened along the main stream at only a few yards from the road, the coal is decidedly good, being preferred to all others by blacksmiths; but the bed is badly distorted and crushed. It stands at an angle of 45 degrees and varies in thickness from 2 inches to 14 inches within a distance of two or three feet. The sharp dip prevails to nearly half a mile from the valley, where it changes suddenly and becomes not more than 5 or 6 degrees. At

say a mile from the road, Mr. Horton has opened a bed on Stock creek, where the exposure is:

Sandstone	20′
Shale	5′
Coal bed	2′ to 3′
Clay, seen	0′ 8″

The roof is very insecure, the shale being slickensided in nests, and a serious fall was seen at 30 feet from the mouth of the pit. The coal is regular, shows no signs of crushing such as those observed in the higher bed and is an excellent fuel for domestic use. It contains a good deal of pyrites and blacksmiths complain that they need much borax when using this coal. Not a little mining has been done here and some of the coal has been carried to Estillville, nearly 20 miles away.

The higher bed is evidently the same with that seen in Pennington's gap under the "Bee Rock." Its characteristics and those of the rock above and below it are the same with those observed in that gap. The lower bed is not shown in the gap and it must belong somewhere in the ill-exposed interval, No. 7 of that section, as bold cliffs of conglomerate were seen below it. The interval between the two beds cannot be determined without careful instrumental measurement.

The upper bed has been opened by Mr. H. Stone at about a mile further up Hunter valley. His pit has fallen in and the bed is concealed, but its features as described by Mr. Stone are similar to those observed at Mr. Bailey's pit. Coal blossoms occur at several places on Cove creek, a tributary to Clinch river flowing from the valley across the fault; but no attempt has been made to ascertain either the thickness or the quality of the coal. Mr. Pinckney Carter has opened two beds on Stony creek. The upper of these is in all probability the same with that opened by Mr. Bailey and Mr. Stone, and it is exposed on Stony creek at somewhat less than one-fourth of a mile above Mr. Carter's house. It resembles a pocket rather than a bed and dips at somewhat more than 30 degrees. The opening extends along the face of the cliff for about 35 feet; the *coal* is three feet thick at the thickest place but pinches out on each side to nothing. More than 10,000 bushels of coal are said to have been taken from this clumsy pit and packed down a rocky trail by the diggers. The *coal* is excellent for blacksmiths' use. Another bed, at probably 300 feet further up the stream calculating in the direction of the dip, is 2 feet thick. A third bed, also about 2 feet thick, which is shown at say one-fourth of a mile up the left hand fork of the creek, has but an insignificant dip. The several openings seen along this stream probably belong to this bed.

Clay iron-stone occurs in moderate quantity in the shaly beds of the Quinnimont group, but there is not enough to be of economical importance.

The peculiar structure of the Hunter Valley fault in the vicinity of Stony creek has been explained in another part of this memoir. The fault appears to be simple until within less than two miles of that creek, and the only

rock shown at the base of the Knox wall is some Hamilton shale. But at Mr. Boatwright's place on Stony creek, the Lower Carboniferous, Hamilton, Oriskany, Lower Helderberg and Clinton were all recognized between the Conglomerate and the Knox group. These seem to come in reversed order as already explained.

The exposure on Mr. Boatwright's property is good. Two beds of the Clinton ore were seen there, which represent the upper and middle beds of the Poor Valley ridge. The upper bed is silicious and no special investigation of it was made. The other was exposed to a thickness of 2 feet for examination and it is said to be 6 feet thick in an excavation now filled up. But this thickness is doubtless an exaggeration, and the excavation may have followed the dip, which is abrupt. *Leptocœlia hemispherica* was recognized in this bed. The ore analyzed by Mr. McCreath yielded :

Metallic iron	43.650
Sulphur	0.008
Phosphorus	0.101
Insoluble residue	31.480

The Lower Helderberg brown hematite is exposed at several localities here on both sides of Stony Creek valley. Samples of the ore analyzed by Mr. McCreath showed :

Metallic iron	41.375
Sulphur	0.060
Phosphorus	0.890
Insouble residue	22.200

But it is clear that the samples from this bed are not altogether fair, as the yield in a forge seems to have been greater than the amount of iron shown by analysis. This ore was digged to some extent for use at the forge on Moccasin creek near Estillville ; but the diggings were abandoned many years ago and the samples were taken from loose pieces which had been weathering for probably 20 years. The limestone of the Lower Helderberg is very fossiliferous and its species ally it closely to the Delthyris Shaly Limestone of the New York group. The Oriskany sandstone is well shown and contains *Streptorhynchus hipparionyx*.

There is little of interest between the Hunter Valley fault and Clinch river. In descending Stock creek, one finds himself constantly in the shales and limestones of the Knox group and the dip is not rapid until near the river. The creek flows through a great tunnel in magnesian limestone. The limestone is so magnesian that the inhabitants of the neighborhood use it as a purgative instead of epsom salts. Midway in the cliff, which overhangs the mouth of the tunnel, is the entrance to a great cave which reaches to within 65 feet of the summit of the hill. The tunnel is 500 feet long, 25 feet high and 35 feet wide. The surveyed line of the Bristol Narrow Guage Railroad passes through it.

The elevated area known as Rye cove is but a little way east from Stock creek. There the dip of the limestones is gentle and the projecting rocks

interfere materially with agricultural operations. Between the mouth of Stony creek and Gray's ford, four miles further up Clinch river, the rocks show that they have described a fold. Along Stony creek, the calcareous sandstones at the base of the Knox group are shown succeeded by shales as near the North Fork of Clinch; above these are massive magnesian limestones containing much oxide of iron and covered with a red soil. But, as in so many other localities, the limestones are so poorly exposed that the structure cannot be made out. Near the river, the shales are shown again and are vertical, giving evidence of having been subjected to enormous pressure.

Copper ridge lies between Clinch river and Copper creek. It consists of three narrow ridges formed by the branches of streams, which flow longitudinally through it. The low divides occasionally render this subdivision obscure, but such obscurity is usually of short continuance. The rocks belong to the Knox and the Trenton and Nashville groups of Safford. The subdivision into ridges is mainly due to the thick cherty beds of the Knox group.

A pyritous calcareous sandstone, holding some limestones, is shown at the foot of the ridge along Clinch river. It bears close resemblance to the calcareous sandstone at the base of the Knox group, so close, indeed, that the writer at one time believed that it was the same and that its presence is due to a fault. But it is not succeeded by shales such as are shown near the Hunter Valley fault.

The dip is abrupt near Clinch river, but becomes gentler within the ridge, only to become abrupt once more toward the southerly side of the ridge.

The cherty rocks of the Knox group carry brown hematites and oxide of manganese, of which fragments occur plentifully along the crests of the minor ridges. Openings have been made at several places to supply ore to White's forge on Moccasin creek; but these have been abandoned for a long time and only fragments of the ore could be found. The manganese at some localities is decidedly good, as appears from Mr. McCreath's analysis of samples from the Salling property, which is as follows:

Metallic manganese	51.495
Metallic iron	0.567
Sulphur	0.000
Phosphorus	0.027
Insoluble residue	3.030

This ore contains 10,141 per cent. of baryta. The percentage of binoxide of manganese is 81.455.

V. Area Drained by the Holston River.

No examinations were made in this area west from the Estillville and Reedy creek road.

The rocks of Moccasin ridge belong wholly to the Knox and the Trenton and Nashville groups, but the higher beds of the latter group are reached only on the northerly side of Clinch mountain. Very good exposures of

that group and of the upper part of the Knox group can be obtained in passing from Clinch mountain through Estillville and thence towards Copper creek, by either the Rye Cove or the Stony Creek road. The higher beds of the following section were seen on the former road, while the lower beds were examined on the latter. There may be an error in No. 15, for that is the horizon at which the two sections were joined, and the thickness of that mass may be greater than is given. All thicknesses are based on estimates, the dip being such that instrumental measurement is necessary for accurate determinations:

Trenton and Nashville Group.

1.	Shale and thin limestone	600′
2.	Limestone and calcareous shale	25′
3.	Calcareous shale	130′
4.	Limestone	70′
5.	Shale	65′
6.	Limestone	45′
7.	Shale	50′
8.	Massive limestones	200′

Knox Group.

9.	Cherty rock and limestone	160′
10.	Limestone and shale	120′
11.	Concealed	60′
12.	Cherty rock	165′
13.	Light blue limestone	55′
14.	Concealed	15′
15.	Limestone, shale and chert beds	300′
16.	Variegated shale	70′
17.	Limestone	250′
18.	Shale	60′
19.	Limestone	260′
20.	Shale	30′
21.	Silicious limestone	200′

Total, Trenton and Nashville, 1185′; Knox group exposed, 1745′

No. 21 is exposed along Copper creek, and is the rock which, in this memoir, has been regarded as marking the base of the upper division of the Knox group. The dip throughout Moccasin ridge is not far from 30 degrees, but the rate increases on Clinch mountain, that at the base of No. 3 being 42 degrees.

No continuous exposure of the shales, No. 1, was seen; but, as far as observed here, the features are the same as on the northerly side of Wallen's ridge. Thin limestones were seen, several of which are fossiliferous. No. 2 is well shown on the side of Clinch mountain at the residence of Mr. R. A. Ayres, opposite the village of Estillville, where it consists of limestone, 2′; calcareous shale, 10′; ferruginous shale, 5′; limestone, 8′. The upper limestone is impure, irregularly bedded, and contains a few

fossils; the lower limestone is light gray, weathers blue, is richly fossiliferous, and contains some pyrites. No. 3 is shown at the same locality, and also along the road from Estillville to Moccasin gap. It consists of red and brown shales on Mr. Ayres' property, more or less calcareous, with some beds of limestone, which become more important at the exposures near Moccasin creek. No. 4, as exposed along the road to Mr. Ayres' house, is an almost continuous mass of limestone, much of it in thick beds, and some parts of it fossiliferous. Several of the thicker layers are streaked with white calcspar. The color varies from flesh-color to light gray, and there are parts which should take a high polish and be valuable as marble. But the greater part of the mass is somewhat argillaceous, and the weathered surface shows many flaws and distinct lamination. The unequal composition of some of the thick beds unfits them for ornamental use, and their unequal resistance to the weather unfits them for building purposes. This series is well shown along the foot of Clinch mountain for many miles.

No. 5 and 6 are much alike, the great difference being in the relative quantity of limestone and shale, limestone predominating in the lower and shale in the upper bed. The limestone is more or less nodular in both. This mass reaches to the "bottom" of Little Moccasin creek and is well exposed on Mr. Ayres' property. No. 7 is concealed in the immediate vicinity of Estillville, but a roadside exposure shows it to be filled with yellow shale.

No. 8 is an important mass, economically as well as stratigraphically. It includes the marbles of the series. The beds are all massive, from 10 to 20 feet thick, and are separated by thinner beds of shale. Many of them are finely granular, others have a conchoidal fracture; the colors are light gray, dark gray, reddish or flesh-colored, brown and nearly black. Some of the beds are streaked with white calcspar, others are fossiliferous, with the fossils replaced by calcspar, so that the rock is beautifully mottled. This effect is most striking in the reddish marbles, some of which are in no wise inferior to the Tennessee marbles used in the National Capitol. The beds are so thick that blocks of any desired size can be obtained. These marbles are well shown in the streets of Estillville as well as along the railroad line for several miles beyond that village. They are well exposed at many points along Moccasin creek between Estillville and the Russell county line. The limestone of No. 4 becomes more massive on Moccasin creek than it is nearer Estillville, so that, near the Russell county line, it might be mistaken for the marble. This series is shown in Copper ridge near Copper creek and in Big ridge, beyond Clinch river near Speer's ferry.

No. 9 is cherty. The bed immediately underlying the marbles is 12 feet thick and contains very little limestone. The rock directly under it is purer and has streaks of calcspar with lumps of chert; but the chert gradually increases downward until, at little more than midway, it predominates. With it are some beds of reddish sandstone. Toward the base, the limestone increases. This mass is well exposed on the Rye Cove road at barely half a mile from Estillville and its base is reached at a few yards above the

mill. It is the first ore horizon of the Knox group. The extensive deposit of brown hematite on Col. Shoemaker's property near Estillville evidently belongs here, as does also the fine deposit on the Big Branch of Moccasin creek at about 8 miles from Estillville. The quality of this ore is good, as appears from Mr. McCreath's analysis of samples from Col. Shoemaker's property, which is as follows:

Metallic iron	58.233
Sulphur	0.053
Phosphorus	0.075
Insoluble residue	3.840

Ore occurs at this same horizon on Copper ridge, having been opened on the McClennan property, near the Nickelsville road.

No. 10 is not fully exposed on the Rye Cove road and is better shown on the Stony Creek road. The limestone beds are from 5 to 15 feet thick and are separated by beds of shale from 10 to 20 feet thick. Very little chert was seen here. The interval, No. 11, is almost wholly concealed on the Rye Cove road and is but imperfectly exposed at other localities. On the former road, it is covered with red soil holding much jaspery rock and an excavation near its base has uncovered a thin silicious bed. At some imperfect exposures, seen elsewhere, it contains much white cherty rock. In all probability it is but a continuation of No. 12, which is very silicious and cherty in its upper part; but the limestone increases below, where chert is present only in irregular masses, which bear much resemblance to colonies of *Stromatopora*. Everywhere it shows more or less of oxide of iron and some of its cherty beds are honeycombed. Small pockets of black shale were seen in several places. This is the second ore horizon and many tons of brown hematite have been taken from it on Mr. Morrison's property near Estillville.

No. 15 is not shown in detail at any locality, but it is one of the most important members of the group, having been distinctly recognized at many localities along the summit of Moccasin ridge and along the middle and northern lines of summits in Copper ridge. For 50 or 60 feet, it is a silicious limestone, more or less ferruginous and cherty, which passes downward into a cherty rock resembling those already described and containing numerous thin beds of light gray sandstone. Below the middle a tight blue limestone occurs, which weathers dirty white, and is persistent, having been observed at many places on both Moccasin and Copper ridges. Toward the base the mass becomes more and more calcareous until it passes finally into a coarsely granular massive limestone. The cherty beds are the horizon at which some of the most important ore deposits occur, brown hematite having been obtained at Mr. Poston's, in Moccasin ridge near Estillville, as well as at several other localities along that ridge; while on Copper ridge, extensive digging has been done at four places and fine blossoms were seen at many others. Oxide of manganese occurs here at one locality on Moccasin ridge and at two on Copper ridge. The manganese underlies the iron.

The limestones of No. 17 are well shown only on the northerly side of Moccasin ridge along the Stony creek road as it descends to Copper creek. They vary from flaggy to massive, from silicious to very pure, and for the most part are gray. Balls of chert were seen in some of the beds. Nos. 19, 20 and 21, are practically one. The upper part is massive and a fairly good limestone; it contains some fossils but they are indistinct. Further down, the rock becomes flaggy or thinner bedded and the silica increases, until the whole is little more than calcareous sandstone. Pyrites begins near the bottom of No. 19 and increases to the bottom of No. 21. This rock bears remarkably close resemblance to that which lies at the base of the Knox group along the line of the Hunter Valley fault.

Clinch mountain is a bold rugged ridge, very narrow, and showing a sharply serrate crest. For nearly 50 miles it has but one water gap, and its slopes are so steep that no wagon road passes over it within Scott county, while trails for riding animals are few and difficult.

The Medina sandstone is reached at the summit of the mountain, and for a long distance forms the southerly slope, the newer rocks being found only near its foot. It is exposed imperfectly in Moccasin gap, but its composition is shown there better than at any other locality within Scott county. The succession as there observed is as follows:

1.	Massive sandstone, much of it conglomerate, dark gray to almost milk white	75′
2.	Massive sandstone, almost like quartzite, no grains shown on weathered specimens; weathered surface is rough and jagged; color on fresh surface, bluish white	150′
3.	Concealed, but evidently containing some shale as well as some white sandstone	30′
4.	Like No. 2 except that in some portions the surface of weathered specimens glistens, while the other always shows a dead white surface; weathered surface irregular	60′
	Total	315′

In many respects, this rock bears much resemblance to the silicious beds of the Knox group; so much, indeed, that one would find difficulty sometimes in deciding the relations of a hand specimen.

Immediately above No. 1 of the section, there is in the gap a hard flinty rock belonging, in all probability, to the Lower Helderberg. It is irregularly bedded, loaded with oxide of iron, contains no fossils, and is not more than 15 or 20 feet thick. Above this come the Hamilton shales. The Clinton group and the Oriskany sandstone are evidently absent.

The Medina carries a brown hematite which has been examined at 3, 6, and 14 miles east from Moccasin gap. Samples taken from Mr. Ayres' property at 3 miles above the gap were analyzed by Mr. McCreath, with the following results:

Metallic iron	43.825
Sulphur	0.029
Phosphorus	0.926
Insoluble residue	19.910

Ore from another locality was mined for White's forge on Moccasin creek, and it is said by Mr. White to have proved even better than the ores from Moccasin ridge.

The Lower Helderberg is fairly well shown at little more than 2 miles east from Moccasin gap, where a fine grained sandstone, almost a true grit, rests on the Medina conglomorate. It contains many fossils, mostly indistinct, among which are *Spirifer* and *Platyceras*, nearly allied to Lower Helderberg forms. This rock shows no traces of iron ore, but immediately above it is a fossiliferous brown hematite, which has evidently replaced a limestone bed. The ore is bulky, and consists chiefly of casts of a *Favosites*, which is somewhat coarser than *Favosites helderbergiæ*, and resembles more a form occurring in the Coniferous. A cyathophylloid coral was obtained from the ore, but it has been misplaced. No other exposure was found.

The Hamilton shales are exposed at the mouth of Moccasin gap and thence to a considerable distance up the side of Brushy mountain. Above these are the Chemung sandstones, containing *Spirophyton* and *Spirifera disjuncta*, and forming the crest of Brushy ridge, the first ridge of Brushy mountain. The second ridge of that mountain is made up of Lower Carboniferous rocks, which continue along the Reedy creek road, to say a mile beyond the North Fork of Holston river. They describe a synclinal at the river. The abutments of the river bridge were constructed of rock from one of the higher limestones, which is composed almost wholly of *Fenestella*. The highest beds of the Lower Carboniferous are mostly bluish grits, with some impure limestones, and are well exposed along the road as it follows a little ravine beyond the Holston river.

The fault of North Fork of Holston is reached along this road at about a mile from the river or near the head of the narrow gap just referred to. This uplift brings the limestones and cherts of the Knox group again to the surface and these continue as the surface rocks to the Tennessee line. Their features are the same as on Moccasin ridge.

A "poor valley" between Clinch mountain and the first ridge of Brushy mountain, extends from the Tennessee line to far beyond the limits of this reconnaissance in Washington county. The Hamilton shales are exposed at many localities in it, but the succession of the group is obtained best by tying the partial section made in Moccasin gap to that made along the railroad grade between Mendota and the North Fork of Holston. The estimated thicknesses are as follows:

1. Dark sandy shale, fossiliferous, shown in the railroad excavations ..... 130′
2. Yellow to ash colored shales, mostly well exposed in the railroad excavations, but the base seen only on the Abingdon road between Mendota and Moccasin gap; dip 45 to 50 degrees ..... 550′

3. Dark fissile shale, with thin beds of sandstone, partial exposures between Mendota and Moccasin gap, but best shown in the gap	150′
Total	830′

The sandstone beds in No. 3 are fine-grained, very white and prove to be an excellent firestone. These are shown in the Abingdon road at several localities between Mendota and Moccasin gap, as well as just below the mouth of the gap. Much of this material was used for lining at Bushong's furnace, 40 miles away in Tennessee, to which it was carried by wagon. The shales are very dark, and at many localities along the foot of Clinch mountain they are as badly wrinkled as mica schist, but they show no evidence of metamorphism. Two thin beds of highly carbonaceous shale occur at the base of this group, which have been mistaken at several places for *coal*. They contain enough carbonaceous matter to burn and sometimes they yield a piece of fairly good *coal*.

The Chemung rocks are shown in all the ravines crossing the first ridge of Brushy mountain. An excellent exposure is afforded by the railroad excavation near the North Fork of Holston river, where the group is represented by shales and sandstone, mostly brownish gray and not far from 300 feet thick. A conglomerate layer, 4 to 6 inches thick, was seen very near the top and another of about the same thickness at 20 feet lower. Fossils were found immediately above the upper layer as well as at 10 feet below it; among these are *Spirifera disjuncta*, *Atrypa aspera* and a *Chonetes*. For the most part the specimens are badly preserved, as the layers in which they occur are ferruginous grits and the fossils are recognizable only on the weathered surface. *Spirifera disjuncta* and *Productella boydii* were found on fragments of sandstone belonging midway in the group, and a *Spirophyton* covers many layers near the base.

The Chemung is succeeded by the lower member of the silicious group of the Lower Carboniferous. The two groups are conformable, and the junction is well shown in the railroad cut.

A good section of the Lower Carboniferous was obtained between this point and the Holston fault by following the railroad line. It is as follows:

Mountain Limestone Group.

1. Sandstones, limestones and shales	800′
2. Calcareous shales	60′
3. Concealed	40′
4. Calcareous shale	100′
5. Limestone	105′
6. Imperfectly exposed	250′
7. Limestone	15′
8. Shales	20′
9. Limestone	50′
10. Shale, imperfectly exposed	65′
11. Limestone	15′

12.	Shale	80′
13.	Limestone	5′
14.	Shale	75′
15.	Limestone	20′
16.	Shale	150′
17.	Limestone	5′
18.	Shale	60′
19.	Limestone	80′
20.	Argillaceous limestone	60′
21	Granular to argillaceous limestone	100′
22.	Argillaceous limestone	35′
23.	Concealed	25′
24.	Granular limestone	30′
25.	Granular limestone	25′

Silicious Group.

26.	Cherty limestone	70′
27.	Granular limestone	35′
28.	Cherty massive limestone	65′
29.	Concealed	10′
30.	Limestone	30′
31.	Concealed	50′
32.	Limestone and shale	40′
33.	Massive limestone	125′
34.	Shales and thin limestones	90′
35.	Limestone	80′
36.	Calcareous shale	35′
37.	Limestone	25′
38.	Shales, sandstones and calcareous grits	100′

Total, Mountain Limestone group, 2270′ ; Silicious group, 755′

These thicknesses are all estimated, except those from No. 7 to No. 15. No. 1 was seen in the gorge of Wolf creek ; Nos. 2 to 20 inclusive were obtained along Abraham creek ; Nos. 21 to 30 inclusive are exposed in the river bluff below the railroad bridge ; and Nos. 31 to 38 are shown in the railroad excavations along the river bank.

No. 1 shows much the same features as in Pennington's gap, as well as along the road leading south-east from Moccasin gap. Its base is reached at the forks of Abraham's creek, at say one mile from the North Fork of Holston river. This mass forms the left hand wall of Wolf Creek gorge, through which the railroad passes for several miles. Here, doubtless, a detailed section could be obtained, but the wall is very steep and its ascent would be attended with danger. The greater part of the rock is a more or less ferruginous calcareous grit, much of which is dark blue on the fresh surface ; but the iron and lime are easily leached out, so that, on exposure, fragments become "rotten" to a depth of several inches. Some portions are very fine-grained and hard, so as to be fit for grindstones ; these are

well shown on a fork of Wolf creek, known as Whetstone hollow. A few of the beds are fossiliferous, but nothing can be obtained from a fresh piece, while the weathered specimens are so tender that specimens are ruined in the effort to free them from the rock. Huge stems of crinoids and some indistinct specimens of *Chonetes* were seen. The limestones are light blue, argillaceous and non-fossiliferous. The shales are usually reddish, but they form only a small part of the mass. No massive sandstone was observed here such as was seen in Pennington's and Big Stone gaps.

Nos. 2, 3 and 4 probably should be accounted as part of No. 1, but the shales, for the most part, are calcareous and resemble some lower beds more than they do those of Wolf creek. The shales, Nos. 8, 10, 12, 14, 16 and 18 are light blue to reddish blue on the fresh surface and weather to a dirty or muddy yellow. A fresh edge seldom shows lamination, but the weathered surface shows it distinctly. These beds are generally well exposed in the bed of Abraham's creek, along side of which the railroad grade runs. Fossils occur rarely in these shales, and the only distinguishable specimens seen belonged to a broad form of *Spirifera leidyi*.

The limestone, No. 5, well exposed at the roadside and in the hills at but a little way below the mouth of Wolf creek, is blue, but weathers yellowish white; it is composed chiefly of a *Fenestella*, but some layers have many specimens of *Athyris* and *Productus*. Nos. 7 and 15, both of which are well shown in the creek bed as well as in the hill, have a similar origin, and the *Fenestella* is distinctly shown throughout with only a rare *Productus* and *Zaphrentis*. These two beds are exceedingly hard. No. 15 is the same with that of which the bridge abutments for the Reedy Creek road were constructed at the North Fork of Holston river.

No. 6 continues from Mr. Kaylor's residence on Abraham's creek down the stream almost to his mill, at probably two-thirds of a mile from the river. It has more than one bed of limestone and is closed by a sandstone at the top. Below this interval, the section is almost continuous to the base of the series. No. 9 is shown at the mill; it varies from light to dark blue or almost black, and shows many stems of crinoids, with *Fenestella* and a *Spiriferina* closely allied to *S. kentuckensis*. No. 11 is a handsome light blue limestone and contains *Athyris subquadrata*, *Productus cora* and crinoid stems, which occur also in Nos. 17 and 19. No. 21 is an important bed, which is shown at the mouth of Abraham's creek and forms a broad band on the cliff around the bend of the river below the railroad bridge. For the most part, it is coarsely granular and dark gray, but it contains some argillaceous layers and becomes a blue grit near the base. It yields an admirable building stone, of which the bridge abutments and pier have been constructed. The rock is very pure and burns into a beautifully white lime, which shows no trace of iron when slaked.

No. 22 is argillaceous and its fragments cover the narrow bank below the bridge. This is by far the most fossiliferous bed of the whole series; *Productus cora*, *Productus elegans*, *Athyris subquadrata*, *Spirifera leidyi*, *Hemipronites crassus*, *Pinna* and *Allorisma* having been obtained from a

small block. Perhaps this should include also the concealed interval below it.

Nos. 24 and 25 are very similar to No. 21; they are granular, and No. 24 is massive. No. 25 is more or less flaggy, and passes into a hard, cross-bedded calcareous grit, which contains not a little chert.

The limits of the two groups are very distinct, and only a few feet at the bottom of No. 25 mark the transition. Below that line, chert is present in nearly every bed. Nos. 26, 27 and 28 are alike, except that very little chert occurs in No. 27. Many layers of No. 26 are crowded with bryozoans, and the smaller nodules of chert are casts of *Productus*. Crinoid stems are abundant in No. 28, which is massive and cherty throughout. No. 33 is well exposed in the railroad excavation: its higher beds are dark gray, streaked with white calcspar and contain much chert, some of which certainly has replaced a *Chætetes*-like form. Fossils occur in the highest beds, where sections of *Productus*, *Athyris* and *Pleurotomaria?* are abundant; the lower beds are massive, almost black, and show only minute fossils. No. 35 is very cherty in its upper and massive layers, but the lower layers are somewhat flaggy, show little chert, and are crowded with crushed fossils, chiefly *Hemipronites* and *Athyris*. No. 37 is flesh colored to light blue, and is well exposed at the mouth of a hollow nearly half a mile from the bridge over North Fork of Holston. There it describes a short abrupt anticlinal, which is nicely shown in the railroad side-cutting. This bed is the base of the upper member of the Silicious group.

No. 38 is the Protean member of the Silicious group. It is not fully exposed as the little hollow, already referred to, intervenes between the last exposure of the limestone and the first exposure of this mass, the concealed interval being perhaps 35 or 40 feet. But under the petty anticlinal, the upper part of No. 38 is shown within 5 feet of the limestone, the interval being filled with some drab clay, which may belong with either No. 37 or No. 38. The upper part of No. 38, as far as seen, is a fine-grained sandstone with smooth fracture, but this passes downward into shales containing a bed which is highly carbonaceous. The rocks below are fine-grained sandy shales with beds of blue calcareous sandstone or grit, very fine-grained and breaking with irregular fracture. These are very similar to the beds seen in No. 1 of the section. It is possible that *coal* occurs in the concealed part of this mass, for a *coal bed* is said to be present under the river directly opposite the mouth of the little hollow. The only fossil seen in these rocks was a fragment, which probably belongs to *Leiorhynchus*.

These beds rest comformably on the Chemung, as already stated.

The dip of the rocks varies. In No. 35 it is nearly 20 degrees; in No. 25 it is 33 degrees and the strike is N. 60° E. mag.; but here the rate increases, and in No. 24 it becomes 40 degrees, which is the prevailing rate of dip up to within 300 yards of the mouth of Wolf creek, beyond which no measurements were made. It is not at all improbable that a fragment of the Quinnimont group remains on the high land between Abraham's creek and Wolf creek.

The Holston uplift is reached at the summit between Wolf creek, North Branch, and the "rich valley" of Abraham's creek. There, one comes to the limestones of the Knox group, in contact with the highest rocks of the mountain limestone group, and two miles further along the railroad line the cherty beds of the Knox group are exposed. These are shown very near to Walker's mountain at a cross-road, where the soil is very ferruginous. The limestones of the overlying group are shown at but a little way from the gap by which the railroad passes through Walker's mountain.

A well-marked fault was crossed just behind Walker's mountain at somewhat more than four miles from Bristol, where the pyritous calcareous sandstones of the Knox group are shown in the gap through that ridge. The dip is abrupt at the head of the gap and increases to the mouth, where it becomes nearly 50 degrees, and the shaly layers are badly twisted. Exposures are very obscure between this locality and Bristol, where the line of section terminated; but the limestones of the Knox group are shown here and there, and the cherty beds of that group pass very near to Bristol.

Photodynamic Notes. By Pliny Earle Chase, LL.D.

(*Read before the American Philosophical Society, January* 21, 1881.)

1. *Chemical Synchronism.*

Maxwell* appears to have originated the theory, which is now generally accepted, of the equality of mean *vis viva* in the molecular movements of different gases, at equal temperatures. In 1863, I began to investigate some of the consequences of the theory, and the many evidences which I have adduced, of cyclical and harmonic vibrations in atmospheric and æthereal media,† have more than justified my belief of its importance.

All harmonies in elastic media necessarily involve some form of synchronism, and the progress of chemical physics may be helped by a knowledge of the general kinetic laws upon which such synchronism depends. If we designate velocity by v; density, by d; time of rotation, by t; modulus, by h; absolute temperature, by T; and the acceleration of a central force, by f, Maxwell's theory may be represented by the equation $v^2 d = k T$. In the fundamental equations of central force $v = \frac{f t}{2} = \mathrm{F} \sqrt{fr}$; $h = \frac{f t^2}{4}$. When the efficient or fundamental velocity is constant, as in spatial Photodynamics, $f \propto \frac{1}{t} \propto \frac{1}{h} \propto \frac{h}{t^2} \propto \frac{1}{r}$; $t \propto h \propto \sqrt{\frac{h}{f}} \propto r \propto \frac{1}{f}$; $h \propto r \propto \frac{1}{f} \propto f t^2 \propto t$. Whenever we have occasion to consider derivative or second-

* P. Mag., 1860 [4], 19, 19.

† Proc. Amer. Phil. Soc., ix, 284-7; xvii, 109-12, 294-307; xviii, 224-32; xix, 4-9 20-5; *et al.*

ary velocities, the equations of variation, for any temporary constancy of f, t, h or r, can be readily found. In the investigation of spectral lines, chemical atomicities, and general kinetic phenomena, both cosmical and molecular, the consideration of f as a maximum often becomes especially important. Then it is evident that $f \propto \left(\frac{r^3 d}{r^2} = r\,d\right)$; $t \propto \sqrt{\frac{r}{f}} \propto \sqrt{\frac{1}{d}}$; the limiting time, therefore, becomes independent of distance, and is merely a function of density. In other words, *in a homogeneous medium, all analogous motions which are due to the accelerations of a central force, whether of rotation, vibration or translation, are synchronous.* In whatever way those motions may be affected by atomic, or molecular rotation, $v \propto r$, without any tendency to the production of internal disturbance. All cyclical harmonies and deformations must, therefore, be due to elasticity, or some other form of translatory interaction. In consequence of the proportionality of rotating velocity to the distance from the centre of rotation, it becomes possible to combine chemical elements of the most various densities; for, while there is perfect synchronism in the normal oscillations of each of the elements respectively, the atoms may intersect with radii which give them equal velocities of rotation at the locus of intersection, so as to produce secondary and subordinate synchronisms, such as are indicated by the harmonies of spectral lines, especially in Lockyer's "basic lines"* and in the lines of the widely diffused and important elements, Oxygen and Hydrogen.† As an illustration of the harmonies of independent and combined synchronism, we may take the three atoms, $H_2\,O$, condensed into two atoms of watery vapor. In rotation, induced, either directly or remotely, by the fundamental efficient velocity of light, we have seen that $t \propto \sqrt{\frac{1}{d}}$ and $v \propto \frac{r}{\sqrt{d}}$; therefore $d\,v^2$ is constant, in each of the elements, and in the compound, *e. g.*:

$$O\left(d = 16;\ v \propto \frac{r}{4}\right) + 2\,H\left(d = 1;\ v \propto r\right) = 2\,H_2\,O\left(d = 9;\ v \propto \frac{r}{3}\right)$$

and four oscillations of O are synchronous with one of H and three of $H_2\,O$.

Such varied evidences of synchronism, both *a priori* and *a posteriori*, may well encourage specialists, in all departments of physical science, to seek for harmonies, under the guidance of the "scientific use of the imagination." We may be assured that such harmonies are abundant everywhere, and we may also be assured that whatever harmonies we find are neither fortuitous nor lawless, although we may, in some cases, be unable to find any other reasons for their existence than the universal canon of nodal action. The more we study the detailed and coördinated ramifications of such action, the greater will be our appreciation and admiration of the order which is "heaven's first law," and the more confidently we can go on with our researches.

* Proc. Amer. Phil. Soc., xviii, 225-6.
† Ib., xix, 25.

2. *Magnetism.*

One of the fields in which there seems to be encouragement for much special investigation, is Electro-magnetism. I gave many reasons, sixteen years ago,* for regarding all magnetic phenomena as results of locally modified vibrations, and on that account I have always thought it to be somewhat illogical to speak of light as "an electro-magnetic phenomenon," thus subordinating the general to the special. According to the law of parsimony, the element of a common velocity indicates a common origin in radiant energy, but in denoting that energy it seems better to use a name which is universally recognized as appropriate, than one which may probably represent a mere local phenomenon. Among my reasons for adopting this opinion was the delay in the manifestations of solar influence. Father Secchi observed a remarkable solar outbreak on the 7th of July, 1872, which produced a great agitation of terrestrial magnetism, and Airy estimated the time required for the propagation of the magnetic disturbance at 2h. 20m. This is 16.87 times the time required for light to come from the Sun to the Earth, which is almost precisely the ratio between the time of terrestrial rotation and the time of satellite revolution at the Earth's surface.

More than seven years after I had shown that the solar daily variations of terrestrial magnetism might be very closely represented, both in form and magnitude, by solar tidal action, Maxwell suggested the same hypothesis.† I showed, in 1875,‡ that my hypothesis led to a simple estimate of Sun's mass, which I placed upon record, without, however, giving all the data for the calculation. The total terrestrial magnetic force in Great Britain has been found to be 10gr. ft. sec.; then the tension, perpendicular to the lines of force, is .128 gr. weight per sq. ft. The greatest magnetic tension which Joule was able to produce in Great Britain, by means of electro-magnets, was about 140 lbs. weight on the sq. in. ($= 140 \times 144 \times 7000 = 141120000$ gr. pr. sq. ft.). The unit of *vis viva*, in mechanical measure, varying as the square of the unit of velocity, is $m^2\, l^2\, t^{-4}$. But the molecular oscillation, in alternate approach to and recess from the orbital centre, continues for a half rotation or a half revolution, while the terrestrial antagonism lasts only $\frac{1}{\pi}$ as long. Therefore, if we designate Earth's mass by a subscript accent (m_1), the ratio of the magnetic force which is due to modified solar radiation, should bear the same ratio to the force of terrestrial reaction, as $m^2\, l^2\, t^{-4} : m_1{}^2\, l^2\, t^{-4}\, \pi^4$, or as $m^2 : m_1{}^2\, \pi^4$. This gives the proportion $m^2 : m_1{}^2\, \pi^4 :: 141120000 :: 128$, or $m : m_1 :: 327710 : 1$.

Although this result is nearly identical with the one deduced from the comparative leverage of Sun and Jupiter (327897), in the paraboloid of interstellar photodynamic action, I am inclined to think that it may be about one per cent. too small. When the difficulty of making precise magnetic

* Ib. Vol. ix, etc.
† Treatise on Electricity and Magnetism, II, 127.
‡ Proc. Amer. Phil. Soc., xiv, 607-9.

measurements is considered, so slight a difference as this is hardly worthy of notice.

The experiments, which I performed before the Society in 1864 and 1865,* appear to have furnished the first direct and positive evidence of the hypothesis that electricity and magnetism consist simply of æthereal vibrations, which can be imitated and modified by simple mechanical means. This mechanical modification led, subsequently, to the invention of the telephone and the photophone.

3. *Earth's Orbital Eccentricity and its Correlations.*

The photodynamic importance of the centres of nucleation, condensation and nebulosity (Sun, Earth and Jupiter), in the solar system, and the tendencies to secondary and subordinate synchronisms, are further shown in moduli of rotation and in orbital eccentricities. The modulus velocity $\left(\frac{gt}{2}\right)$ of Jupiter is slightly greater, while that of Earth is slightly less, than Sun's wave velocity $(\sqrt{g_0 r_0})$; the slight differences being due, apparently, to the same causes as Earth's apsidal oscillations and its mean deviation from the centre of the belt of greatest condensation. Jupiter's secular range, from secular perihelion to secular aphelion ($.63295\rho_3$), is nearly the same as Earth's orbital radius of spherical gyration ($\sqrt{.4} = .63245\rho_3$); Jupiter's ratio of minimum eccentricity (.02549) is about three-quarters of Earth's ratio of mean eccentricity ($\frac{3}{4}$ of $.03387 = .02540$); at Jupiter's secular perihelion, or locus of rupturing oscillation, the projections of Sun's and Jupiter's centres from Sun's surface ($.93917 \times 5.2028 \times 214.55 = 1 + 1047.37$) are inversely proportional to their respective masses. We may, therefore, not unreasonably expect to find similar simple relations between different forms of terrestrial eccentricity and cosmical *vis viva*.

If we suppose the air to be condensed to the homogeneous density which is indicated by the theoretical velocity of sound, we may assign .4 of its velocity of equatorial rotation to the mean *vis viva* of simple spherical rotation, and the remaining .6 to æthereal or elastic action. The velocity of rotation is $2\pi \times 3962.8 \times 5280 \div 86164 = 1525.77$ ft.; the theoretical velocity of sound, $\sqrt{gh}$, should, therefore, be $.6 \times 1525.77 = 915.46$, and the height of homogeneous atmosphere $915.46^2 \div (32.088 \times 5280) = 4.9466$ miles.

This closeness of accordance with the values which have been derived from observation, accounts only for the equilibrium between the elastic and gravitating actions of daily rotation. The atmospheric particles, in their undulatory motion with the velocity of sound, may be regarded as traversing orbits with a mean eccentricity of $\frac{h}{r} = \frac{4.9466}{3962.8} = .0012483$. This result has been obtained by regarding the atmosphere as homogeneous, in the same way as our photodynamic results were obtained by regarding Sun's

* Ib., ix, 359; x, 151-66.

æthereal or luminiferous atmosphere as homogeneous. Therefore, if we consider Earth's mean orbital eccentricity as due to the elastic reaction of the nebular centre of oscillation (Jupiter) against the nucleal centre (Sun), we find :

Earth's mean atmospheric ecc'y : Earth's mean orbital ecc'y :: (Earth's semi-axis major)^2 : (Jupiter's semi axis major)^2; which gives .0012483 : .0033789 :: 1 : 5.2028^2. In order to acquire the velocity due to this eccentricity, there should be a fall of the centre of condensation (Earth) from the centre of the dense belt of planets, through one-half the height, or .016895 Earth's semi-axis major. In order to make the efficient wave producing *vis viva* at Earth equivalent to that at Sun's surface, we should take account both of Earth's (1.) and Jupiter's (.033789) action, as is done in the equation $1.033789 \frac{gt}{2} = \sqrt{g_0 r_0}$. Substituting $g = 32.088 \div 5280$, and $t = 86164$ sec., this gives 270.67 miles $= \sqrt{g_0 r_0}$. From this velocity we can readily deduce Earth's orbital velocity, which, being multiplied by the number of seconds in a sidereal year and divided by 2π, gives $270.67 \div \sqrt{214.55} \times 31558150 \div 2\pi = 92812000$ miles, for Earth's semi-axis major. The closeness of agreement between these photodynamic results and other estimated values is shown in the following table :

	Photodynamic.	Calculated from observation.		Difference.
Jupiter's secular range,	$.63245\rho_2$	Stockwell,	$.63295\rho_2$	.08 of 1 pr.ct.
" minimum ecc'y,	.02540	"	.02549	.36 "
Mass, Sun ÷ Jupiter,	1047.37	Bessel,	1047.88	.04 "
Theoretical vel. of sound,	915.46	Enc. Met.	916.322	.09 "
Homogeneous atmosphere,	4.9466	Silliman,	4.9478	.03 "
Earth's mean ecc'y,	.033789	Stockwell,	.0338676	.23 "
" " orbital fall,	.016895	"	.0169394	.26 "
" semi-axis major,	92812000	Cornu,	92803000	.01 "

4. *Cosmical and Molecular Densities and Velocities.*

We have seen that the function $t \propto \sqrt{\frac{r}{f}}$ is independent of any other element than d, when f is a maximum, or when comparisons are made at distances from the centre of force which are proportionate to their respective nucleal or atmospheric diameters. This renders the proportionality $t \propto \sqrt{\frac{1}{d}}$ an important one. For example, it is safe to predict that if the time of rotation of any single star should ever be discovered, it will be found to be such that $\frac{gt}{2}$ will not differ perceptibly from the velocity of light ; and from the times of rotation we can readily calculate the ratios of stellar to solar density. In binary and multiple stars, or in planetary systems where the planetary reactions are so important as either to retard or accelerate the rotary velocity of the nucleal mass, the value of the modulus velocity must still be some function of the velocity of light, although it may be so changed as to leave room for much interesting and perplexing study in seeking the causes and amounts of perturbation. In considering

the equality of molecular *vis viva*, many well known evidences of atomic and molecular rotation have been found, but I know of none which furnish the necessary data for determining in what way the intrinsic rotations, which are due to simple reaction against the undulations of the luminiferous æther, have been modified by the accelerations of terrestrial rotation and the various unknown mechanical influences of chemical physics. The molecular velocity $v \propto \sqrt{\frac{1}{d}}$ accounts for all synchronisms of homogeneous media, but how are we to explain the synchronisms of rotation and revolution in a body so heterogeneous, and, consequently, with such various moments of inertia, as the Earth? If density itself was originally a function of distance fallen through, and, therefore, varied as t^2, the synchronous time for the aggregate of mean motions varied as $\sqrt{d}$. The equation $s = vt$ is, therefore, constant for any given radius. In order that this constancy may prevail, there must be some unit of density to represent either the modified æther, or some gas which is directly subjected to the influence of its vibrations. The hyper-elasticity of hydrogen, its wide diffusion, its continual presence in the solar explosions, the fact that it has the greatest tenuity of any substance which we have been able to measure with precision, its importance in relation to Lockyer's "basic lines," together with the simple and significant harmonic indications of those lines,* all point to it as the probable typical representative, or the transmitter, of primordial undulation. In order to test this hypothesis, let x represent the specific gravity or d of Earth; 270.67 m., the value of $\sqrt{g_0 r_0}$ at Sun, or Earth's modulus velocity of rotation; 6050, the molecular velocity of hydrogen; .0693, the ratio of the specific gravity of hydrogen to that of air; 773, the ratio of the specific gravity of water to that of air; $x \div 1.033789^3$, the mean specific gravity of Earth if expanded to $1.033789 \times$ its present radius, so as to eliminate the condensation due to the action of Jupiter. Introducing these values, in the constant equation $s = vt$, and considering v as the velocity acquired in t, the time of condensation, we have $\frac{270.67 \times 5280}{6050} = \sqrt{\frac{773\,x}{.0693 \times 1.033789^3}}$, and $x = 5.527$. The mean molecular velocity of earth which is due to æthereal elasticity, would then be $6050 \div \sqrt{\frac{773 \times 5.527}{.0693}} = 24.367$ ft. pr. sec.; the corresponding velocity of any terrestrial substance $= \frac{24.367 \times \sqrt{5.527}}{\sqrt{d}} = \frac{57.284}{\sqrt{d}}$ ft., if the density is compared with that of water, or $\frac{57.284 \times \sqrt{773}}{\sqrt{d}} = \frac{1592.655}{\sqrt{d}}$ ft., if air at 0° and 760 mm. is taken as the unit of density. These ratios are important in investigations which involve the modified or specific elasticity of bodies.

* Proc. Amer. Phil. Soc., xviii, 224-6.

PROC. AMER. PHILOS. SOC. XIX. 108. 2H. PRINTED FEBRUARY 26, 1881.

5. *Photodynamic Estimate of Earth's Mass.*

I have shown, in my discussion of "Earth's orbital eccentricity and its correlations" (Note 3), that Sun's surface is the fulcrum of equilibrium between the two principal masses of our system (Sun and Jupiter), at the locus of rupturing projection, or the secular perihelion centre of gravity of Sun and Jupiter. I also showed, in my first paper on photodynamics, that the antagonistic mean leverage of Sun and Jupiter produces disturbances, at the directrix-locus of the stellar-solar paraboloids, which furnish a very close approximation to the ratio between solar and terrestrial superficial gravitating energy. The forces which have established these harmonies must act under special conditions of equilibrium at the centre of condensation (Earth), and it seems probable that those conditions may be less subject to extraneous disturbance than either of the other adjustments which I have investigated.

In the photodynamic paraboloids, at any given instant, let a be the solar locus of the directrix which is on the side of Sun's centre opposite to Earth; s_0, the centre of nucleation, or Sun's centre, regarded as a primary point of suspension for a linear pendulum; s_3, the centre of condensation, or Earth's centre, the secondary point of suspension of the same pendulum; o_0, the centre of a primitive nucleal radius and also the centre of linear oscillation for s_3; o_3, the centre of linear oscillation for s_0 and also the common locus for coördinate radii r_0 and r_3; o_1, the centre of the linear pendulum $s_0 s_3$; o_2 the centre of $s_0 o_0$ and the centre of linear oscillation of $o_1 s_0$; $r_0 = s_0 o_3$; $r_3 = s_3 o_3$; m_0, m_3, homogeneous masses varying as r_0^3, r_3^3; o_3 is the locus, in suspension from s_0, of opposite tendencies towards s_3 and s_0. Then $r_0 = 2r_3$; $m_0 = 8m_3$; if we represent the superficial momentum of any equatorial particle of m_3 by 1×1, the corresponding momentum for m_0, with reference to the same point of suspension (s_3) is 8×3. If the photodynamic momentum is converted into velocity of contiguous particles, at o_3, causing one of the particles to revolve about s_3, and the other, by reaction from s_0, about s_0, their respective velocities will be represented by $\sqrt{g_3 r_3}$ and $\sqrt{g_0 r_0}$, the latter being $(8 \times 3 = 24)$ times the former. Now $\sqrt{gr} \propto \sqrt{\frac{1}{r}}$ while $g \propto \frac{1}{r^2} \propto (\sqrt{gr})^4$. Therefore $g_0 = 24^4 g_3$. But $g \propto m$, in mutual action and reaction, as in the case of Earth revolving and Sun rotating under the photodynamic influence of $gt = v_\lambda$; therefore $m_0 = (24^4 = 331776)\, m_3$. Radius varying as $\left(\frac{m}{d}\right)^{\frac{1}{3}}$, Sun's radius, r_0 should then be $(331776 \div .25527)^{\frac{1}{3}} = 109.07 r_3$; and Sun's mean distance, $\rho_3 = 214.5516 \times 109.07 \times 3962.8 = 92734000$ miles.

6. *Photodynamic Limitation of Terrestrial Day.*

The number and variety of the foregoing harmonies led me to look for some photodynamic influence on terrestrial rotation, or at the centre of density, analogous to that which is indicated by the solar nucleal equation,

at the centre of nucleation, $\frac{gt}{2}$ = velocity of light. The acceleration of sun spots near the solar equator indicates a velocity which is partly rotational and partly orbital. The solar corona is now generally attributed to nebulous or meteoric matter, which is constantly tending either to fall into or to revolve about the Sun. If Sun's surface is the locus of the mean orbital collisions, the mean nebulous radius is $\frac{3}{2}\, r_0$, and the mean locus of the nebulous particles, r_a, is $\sqrt{\frac{3}{2}}\, r_0$. Let t_a be the time of half-rotation for r_a, in the fundamental equation $g_a t_a = v_\lambda$; then $t_a = \sqrt{365.2565} = 19.11168$ dy, is a mean proportional between the solar terrestrial day and the terrestrial year. This gives for t_0, or the photodynamic modulus time at Sun's surface, $\frac{2}{3}\, t_a = 12.741123$ dy. Let n = the number of solar radii (r_0) in Earth's semi-axis major (ρ_3), and we have the equations :

$$v_\lambda = g_0 t_0 = 12.741123 \times 86400 g = n\, r_0 \div 497.827$$

$g_0 r_0 = \left(\frac{n^{\frac{3}{2}} \times 2\pi\, r_0}{31558150}\right)^2 = n^3 r_0^{\,2} \div (5022636)^2$. Hence

$$n = 214.5516.$$

$$g_0 = .0000003915 r_0.$$

$$2\pi \sqrt{\frac{r_0}{g_0}} = 10041.8 \text{ sec.}$$

$$2\pi \sqrt{\frac{r_3}{g_3}} = 5073.6 \text{ sec.}$$

$$\frac{d_0}{d_3} = \left(\frac{5073.6}{10041.8}\right)^2 = \frac{1}{3.9174} = .25527.$$

$$r_0 = 92{,}812{,}000 \div 214.5116 = 432580 \text{ m.}$$

$$\frac{g_0}{g_3} = \frac{r_0 d_0}{r_3 d_3} = 27.8657.$$

$$\frac{m_0}{m_3} = \left(\frac{r_0}{r_3}\right)^3 \times \frac{d_0}{d_3} = 332{,}500.$$

Another evidence of the limitation of the time of rotation, at the centre of condensation, by photodynamic influences, is found in the accelerations which are due to condensation within the present limits of the solar system. The central actions and reactions of acceleration between Sun and Earth vary as their respective masses, because $g \propto \frac{m}{d^2}$ and d is the same. In condensing nebulæ, equality of *vis viva* requires that t (of rotation) $\propto r^2$. From this source, therefore, Earth has been accelerated $(30.034)^2$ times by its "subsidence" from Neptune's mean orbital distance. This acceleration provides only for synchronous solar and terrestrial rotation; there has, however, been a further acceleration of 366.2565, by the shortening of the solar year to the terrestrial day, and of $\sqrt[4]{1.0145}$ by the mean

"subsidence" of Neptune from its secular aphelion, since $\sqrt{gr} \propto \sqrt[4]{g}$. The quotient of Sun's mass by Earth's mass which will account for all these accelerations, is therefore, $\sqrt[4]{1.0145} \times 366.2565 \times (30.034)^2 = 331567$, a value which differs by only $\frac{1}{15}$ of one per cent. from the one last obtained by purely *a priori* indications, and $\frac{1}{3}$ of one per cent. from the one which was deduced from coronal oscillations.

7. *Photodynamic Limitation of Jupiter's Day.*

The centre of nebulosity (Jupiter) presents equally conclusive evidence of photodynamic acceleration, if we pay proper regard to the difference between the expansive reaction of elasticity and the gravitating action of condensation, with its consequent limitation of elasticity. If we take the "centre of primitive annular condensation" (Neptune), at its rupturing locus (secular perihelion $= 29.5982\rho_3$), the photodynamic seat of rupturing action* is at $\frac{4}{9}$ of $29.5982\rho_3 = 16.4434\rho_3$; squaring and multiplying by Sun's mass (1047.879), we get 10467 for the number of rotations in an orbital revolution. Dividing Jupiter's year (4332.5848 dy) by 10467, we get 9h. 56m. 3.4s. for the length of Jupiter's day. Prof. Hall's recent estimate is 9h. 55m. 26.5s.

8. *Moon's Mass.*

In the third note of the present series, I have shown some of the relations of Earth's orbital eccentricity to Jupiter's locus of rupturing oscillation, the masses of Sun and Jupiter, Earth's fall from the centre of the belt of greatest condensation, and the height of Earth's homogeneous atmosphere. The atmospheric elasticity should evidently be in equilibrium, between the mutual inter-actions of Earth and Moon, in the same way as the æthereal elasticity is in equilibrium between solar and planetary actions and reactions. The atmospheric eccentricity being .0012483, the ratio between the lunar and terrestrial masses, in order to be in equilibrium with this eccentricity, should be $\pi^2 \times .0012483$, or Earth's mass should be 81.17 times Moon's mass. What slight modifications of this value may be required, in order to satisfy other conditions, must be left for further investigation.

9. *Earth's Semi-axis Major.*

If we take the photodynamic estimate of the centre of the belt of greatest condensation (1.016895; Note 3), the ratio of r_0 to r_3, as determined by the mean locus of solar and terrestrial action proportionate to mass, should be 1.016895 times $\frac{214.5516}{2} = 109.088$. If we adopt Stockwell's computation of the secular centre of the belt of greatest condensation ($1.016939\rho_3$), the ratio is 109.093. These estimates give, for Earth's semi-axis major, 92750000 and 92754000 miles respectively.

* Proc. Amer. Phil. Soc., xii, 392-4; P. Mag., June, 1877, p. 353.

10. *The Photodynamic Year.*

The constant action of the constant photic energy, at the centre of solar and terrestrial action proportionate to mass, is equally divided between Earth and Sun, so that $g_3 t_2$ for Earth corresponds with $\frac{g_0 t_0}{2}$ for Sun, when so expanded that its rotation would be synchronous with the terrestrial year. We therefore find for the velocity of light, if we allow for the acceleration due to the photodynamic projection of Neptune (Note 6),

$$\frac{g \times 1 \text{ yr. in sec.}}{(\text{Neptune's projection})^2} = \frac{32.088 \times 31558150}{5280 \times 1.0145^2} = 186345 \text{ miles per sec.}$$

Multiplying by 497.827, the time required for light to come from the Sun, we get 92,767,260 miles for Earth's semi-axis major.

11. *Masses of Jupiter and Saturn.*

In consequence of the simplicity of Earth's relation to the centre of condensation, the *a priori* approximation to its mass is comparatively easy; but all the requirements of photodynamic *vis viva* must be satisfied in each of the cosmical masses, as well as in every chemical atom and molecule. Jupiter's synchronous radius, or the distance from Jupiter's centre ($.51231\rho_3$), at which a satellite would revolve in one of Jupiter's orbital revolutions, is 1.0246 × the radius of confluent solar and terrestrial mass action. The time of any circular orbital revolution is ($\sqrt{32} = 5.6568$) × the time of fall to the centre of force. The accelerations of gravity varying as the fourth power of orbital velocity, and acquired velocity varying as gravitating time, the mass, which would satisfy conditions of simple equilibrium between tendencies to condensation and to orbital motion, is $5.6568^4 = 32^2 = 1024$. Sun's mass : Jupiter's mass :: 1047.879 (= 1.0234 × 1024) : 1. This indicates a modification of the equilibrating mass, similar to the modification of the synchronous radius. The difference between 1.0234 and 1.0246 is less than one eighth of one per cent., which is within the limits of probable errors of observation. The rupturing photodynamic ratio ($\frac{5}{8}$; see Note 7), and the ratio of photodynamic projection (1.01455;* see Note 10), have both been introduced, as factors of equilibrium, between the centre of nebulosity (Jupiter) and the nebular centre of planetary inertia (Saturn);† for $(\frac{5}{8} \times 1.01455)^2 \times 1047.879 = 3501.6$ which is Bessel's estimate of the quotient of Sun's mass by Saturn. This deduction of Saturn's mass, therefore, indicates (Note 10) a velocity of light equivalent to $\frac{32.088 \times 31558150}{5280 \times 1.01455^2} = 186326$ miles, and gives, for Earth's semi-axis major, 92,758,000 miles.

12. *Photodynamic Centre of Planetary Inertia.*

Saturn's position, at the nebular or photodynamic centre of planetary inertia, furnishes special and very interesting crucial illustrations of the

* This value is about $\frac{1}{2}\frac{1}{3}\frac{1}{3}$ of one per cent. greater than Stockwell's estimate of that of Neptune (1.0145066).

† Proc. Am. Phil. Soc., xviii, 431.

cosmical influence of harmonic nodes in an elastic medium. Let v_λ be the velocity of light; g_x, the acceleration of gravity at r_x, the radius of Sun's photodynamic sphere; $v_x = \sqrt{g_x r_x}$ = orbital velocity at r_x; v_0 = orbital velocity at r_0 (Sun's surface), and modulus velocity, $\left(\frac{gt}{2}\right)$, for centres of nebulosity and of condensation (Jupiter and Earth), the modulus velocity having been slightly changed, as we have seen, by forces which produce orbital eccentricity; $M_x = \frac{g_x t_x^2}{4}$; r_1, radius of orbital revolution synchronous with nucleal rotation; $\left(\frac{v_\lambda}{v_x}\right)^2 = \frac{M_x}{r_x} = \frac{g_x t_x^2}{4 r_x}$; $M \propto r_x^2 \propto r_1^{\frac{3}{2}}$; $r_1 \propto r_x^{\frac{4}{3}}$; $r_x = \sqrt{r_x r_1} \propto r_x^{\frac{7}{6}} \propto r_1^{\frac{7}{8}} \propto M^{\frac{7}{12}}$; $r_2^{\frac{12}{7}} \propto M$; $r_2^{\frac{6}{7}} \propto M^{\frac{1}{2}} \propto \frac{1}{v_x} \propto \frac{1}{v_2} \times \left(\frac{r_x}{r_2}\right)^{\frac{1}{2}} \propto \sqrt{r_0}$. If we take r_0 as the unit of distance, we have, for the present condition of the solar system, $r_x = \sqrt{M r_0}$; $\left(\frac{r_2}{r_0}\right)^{\frac{6}{7}} = \sqrt{\frac{M}{r_0}} = \frac{v_\lambda}{v_2} \times \left(\frac{r_0}{r_2}\right)^{\frac{1}{2}}$; therefore $\left(\frac{r_2}{r_0}\right)^{\frac{12}{14}} = \frac{v_\lambda}{v_2} = \frac{t_2}{t_\lambda}$. But $\frac{t_2}{t_\lambda}$ = the time in which light would traverse Saturn's orbit, divided into the time of Saturn's orbital revolution; therefore $\left(\frac{r_2}{r_0}\right)^{\frac{12}{14}} = 9.5389^{\frac{3}{2}}$ years $\div$ (9.5389 $\times$ 2π $\times$ 497.825 seconds) = 31160.4; $\frac{r_2}{r_0} = (31160.4)^{\frac{14}{12}} = 2046.8$. This gives for Earth's semi axis major $\frac{2046.8 r_0}{9.5389} = 214.575 r_0$.

13. *Earth's Rupturing or Projectile Locus.*

In Note 6, I have shown the relation of Earth's accelerated rotation to Neptune's subsidence and Sun's mass. In Note 5, I deduced a value for Earth's mass from simple considerations of linear oscillation, between the nebular centre of the solar system and the centre of greatest condensation. Since the stability of the system requires that all its oscillations should be harmonic, we may also account for Earth's rotary acceleration by simple solar and terrestrial inter-actions. The propagation of rays of equal length, in an elastic medium, produces a terrestrial reaction to its orbital motion, through a radius equal to Sun's radius. The centre of linear oscillation, in terrestrial revolution, which limits the tendencies of photodynamic *vis viva* towards the earth, is at only $\frac{1}{3}\rho_3$ from Earth, or near Venus's secular perihelion; the pendulum of solar action upon Earth (ρ_3) is three times as great. The sum of the masses of Earth and Sun being involved in these actions and reactions, there is a consequent acceleration which would give the Earth nine rotations per annum from this source alone. This acceleration is further increased by the rela-

tions of orbital velocity, due to Sun's mass acting through Earth's secular perihelion or projectile radius vector, which may be represented by $\sqrt{\frac{m_0}{\rho_3}}$, and to Earth's mass acting through a radius equal to Sun's semi-diameter, which may be represented by $\sqrt{\frac{m_3}{r_0}}$. Therefore we have the proportion $\sqrt{\frac{m_0}{\rho_3}} : \sqrt{\frac{m_3}{r_0}} :: 366.2565 : 9$. Hence $\frac{m_0}{m_3} = \left(\frac{366.2565}{9}\right)^2 \times \frac{\rho_3}{r_0}$. Introducing Stockwell's ratio for Earth's projectile radius vector (.9322648) we find $\frac{\rho_3}{r_0} = .9322648 \times 214.5516 = 200.02$, and $\frac{m_0}{m_3} = 331252$.

14. *Callisto, Jupiter's Telluric Moon.*

The combined influence of harmonic photodynamic oscillations on the three important centres, of nucleation (Sun), condensation (Earth), and nebulosity (Jupiter), is further shown by the proportion:

Jupiter's isochronous radius : Callisto's semi-axis major :: $\sqrt{\frac{m_0}{\rho_3}} : \sqrt{\frac{m_3}{r_0}}$ :: 366.2565 : 9. Searle* gives for the distance and period of Callisto, $.012585\rho_3$ and 16.689 days. This would make Jupiter's isochronous radius $.012585\rho_3 \times (4332.5848 \div 16.689)^{\frac{2}{3}} = \frac{366.2577}{9} \times$ Callisto's semi axis major $= .51231\rho_3$. The value thus obtained for Earth's sidereal year differs from the observed value by only $\frac{1}{3000}$ of one per cent. Other harmonic influences, analogous to those which we have already considered, are traceable in the following equations: 1. $\left(\frac{2}{3}\right)^4 \times$ Jupiter's mean aphelion projection $\times$ Earth's day = Jupiter's modulus time, or time of half rotation. This gives, for Jupiter's day, 9h. 53m. 26.5s. 2. $\frac{2}{3} \times \frac{\text{Jupiter's semi-axis major}}{\text{Earth's semi-axis major}} \times$ time of revolution at Jupiter's surface = 9h. 54m. 11.6s. 3. $2^4 \times 1.04316 \times$ Jupiter's semi-diameter = $16.69056r$ = Callisto's semi-axis major. 4. $3^3 \times$ Earth's day = Callisto's orbital time (26.9984 dy). 5. Jupiter's modulus velocity ÷ Earth's ratio of aphelion projection (1.0677352) = 271.23 miles. This gives 186830m. for the velocity of light, and 93010000m. for Earth's semi-axis major.

15. *Probable Values.*

I subjoin, for comparison, a few of the results of the foregoing methods of questioning nature, under the simple guidance of the well-known law that every action *must have* an equal and opposite reaction. The dates refer to publication in the Proceedings of the American Philosophical Society.

Flame energy,	Feb. 16, 1872,	92639500
Basic lines,	April 4, 1879,	93203000

* Outlines of Astronomy, Sect. 795.

Earth's orbital unit,	April 4, 1879,	92579000
Cosmical masses,	" "	92549000
Neptune's radius vector,	" "	92717000
Primitive condensation,	Jan. 4, 1880,	92520000
Sun and Jupiter,	" "	92606000
Nodal action,	March 19, 1880,	92711850
Hydrogen,	April 16, "	92756000
Oxygen,	" "	92849000
Undulatory *vis viva*,	Note 3,	92812000
Earth's mass,	" 5,	92734000
Terrestrial day,	" 6,	92714000
Earth's semi-axis major,	" 9,	92752000
Earth's year,	" 10,	92767260
Jupiter and Saturn,	" 11,	92758000
Earth's projection,	" 13,	92590000
Jupiter's day,	" 14,	93010000

These combined results indicate a value, for Earth's semi-axis major, of 92737100m. ± 25700; the probable error being less than $\frac{1}{3}\frac{1}{6}$ of one per cent. This gives, for the velocity of light, 299854 ± 83 kilometres. In the *American Journal of Science*, for January, 1880, pp. 59–64, D. P. Todd discusses Foucault's, Cornu's and Michelson's experimental estimates of the velocity of light. The following table gives his several values, together with Michelson's final estimate (III), and my own:

Foucault	298000 km.
Cornu, I	298500 "
" II	299990 "
Michelson, I	300100 "
" II	299930 "
" III	299820 "
Todd	299920 "
Chase	299854 "

Stated Meeting, February 4, 1881.

Present, 9 members.

Vice-President, Mr. ELI K. PRICE, in the Chair.

Letters accepting membership were read from Dr. Chas. Stewart Wurts, 1701 Walnut St., Jan. 24, 1881; Mr. Henry Carvill Lewis, Germantown, Jan. 25, 1881; Capt. E. Y. McCauley, Lima, Delaware Co., Pa., Jan. 26, 1881; Mr. Addison May, West Chester, Pa., Jan. 26, 1881; and Prof. Joseph Lovering, Cambridge, Mass., Jan. 31, 1881.

Letters acknowledging receipt of Diplomas were received from Dr. E. H. Von Baumhauer, Haarlem, Jan 15, 1881; U. G. Armstrong, Newcastle-upon-Tyne, Jan. 13, 1881; and Sir Wm. Thomson, Glasgow University, Jan. 19, 1881.

A photograph of Dr. Benjamin Howard Rand was presented for insertion in the Album.

Letters of acknowledgment were received from the Astronomical Society at Leipsig (106 and List); and the American Statistical Association, 19 Boylston Place, Boston (106).

A letter of envoy was received from the Meteorological Office, London, Jan. 1881.

A request for missing Nos. 88, 105 and after, from the Cambridge Philosophical Society, England, was, on motion, referred to the Secretaries with power to act.

A request for Transactions Part 3, Vol. XV, for the Numismatic and Antiquarian Society of Philadelphia, was referred to the Secretaries with power to act.

A letter from the Société d'Anthropologie de Paris requesting subscriptions to the Paul Broca monument was read.

Donations for the Library were received from the Senckenburg Natural History Society, Frankfurt a. M.; the Zoologischer Anzeiger, Leipsig; Nassau Natural History Union; Academia dei Lincei; Annales des Mines, and Revue Politique, Paris; Société de Geographic Commerciale, Bordeaux; Meteorological Council and Nature, London; Geological Survey of Canada; Institute of Technology, Boston; Museum of Comparative Zoology and Harvard College Library, Cambridge; American Journal of Arts and Sciences, New Haven; Numismatic and Antiquarian Society, College of Pharmacy, Mr. F. T. Freeland and Mr. Henry Phillips, Jr. Philadelphia; Mr. Thos. H. Dudley, Camden; Historical Society of Delaware, Wilmington; the Bureau of Education, Washington; and the Kansas Historical Society.

Dr. Brinton read an obituary notice of Prof. S. S. Haldeman, a member of the Society.

Prof. J. J. Stevenson communicated a paper entitled "The

Upper Freeport Coal Bed along Laurel Ridge in Preston county of West Virginia." By John J. Stevenson, Professor of Geology in the University of the City of New York.

Mr. Fraley reported by letter that he had received and paid over to the Treasurer the last interest on the Michaux Legacy due Jan. 1, 1881, amounting to $129.60.

And the meeting was adjourned.

The Upper Freeport Coal Bed along Laurel Ridge in Preston County of West Virginia. By John J. Stevenson, Professor of Geology in the University of the City of New York.

(*Read before the American Philosophical Society, February* 4, 1881.)

Laurel ridge, the easterly boundary of Ligonier valley in Pennsylvania, enters West Virginia at or very near the north-western corner of Preston county. It is a bold anticlinal, which in Indiana, Westmoreland and Fayette counties of Pennsylvania, as well as in Preston and Barbour counties of West Virginia, exposes the bottom of the Lower Carboniferous, and at some localities brings up the Chemung rocks, while the Conglomerate and the Lower Productive Coal group, the Allegheny series of Lesley, are shown on its sides. The fold is cut transversely by several deep gaps in Pennsylvania, where it shows no longitudinal valleys of considerable extent; but in Preston county of West Virginia it is divided longitudinally by Cheat river, whose gorge is one of the most noteworthy attractions of the Baltimore and Ohio railroad.

A strip, extending nearly twelve miles along the westerly slope of the ridge in Preston county, and divided by the Baltimore and Ohio railroad, was visited by the writer in December of 1880. The *Upper Freeport Coal Bed*, the most important member of the Lower Productive Coal group, presents some features there which may be deserving of note.

The easterly outcrop of that bed is crossed by the railroad at probably two miles eastward from Tunnelton station, and there, on the Graham-Beall estate, an old opening was examined which showed the following section:

1.	Mahoning sandstone.....	not measured
2.	Shale.....	0′ 3″
3.	*Coal*.....	3′ 10″
4.	Clay.....	0′ 2″
5.	*Coal*.....	1′ 8″

But the exposure at the bottom is not complete, for, underlying the measured portion, is some good coal, and still lower is a considerable thickness of impure slaty coal, which is not worth digging. The coal, as far

as exposed, is very good, more or less prismatic, very soft and easily mined. For the most part, it is clean, but thin streaks of pyrites occur in the top 10″, and minute scales of the same mineral appear occasionally in the bottom 8″. Above the coal and separated from it by but 2 or 3 inches of shale is the hard gray Mahoning sandstone, which lies in thick beds and forms an excellent roof. The exposure of this rock does not give the thickness.

The sandstone is well shown along the railroad between this place and Tunnelton. Owing to the crookedness of the road, the bottom of the rock is sometimes below, sometimes above the track, but rarely many feet in either the one way or the other. Frequently, however, the coal is at track level, and at Tunnelton it is far enough above that to be worked. It descends toward the tunnel beyond the station, but in the tunnel rises again so as to form the roof at the westerly end. Thence, however, the course of the road follows the dip of the rocks, and the coal soon comes down to the track-level, where it is mined and shows the following section :

Coal	2′ 8″
Clay	0′ 2″
Coal	2′ 8″

The exposure is incomplete at the top, but reaches very nearly to the bottom of the good coal. The slaty division below is said to be not far from 3 feet, in which case the full thickness of the bed is about 9 feet 6 inches. The quality of the measured coal here is similar to that of the coal seen at the Graham-Beall pit. Eight inches of the slaty coal were seen. It contains some good splint, but for the most part appears to be worthless. The roof at this pit is shale, which varies in thickness from 2 inches to 12 feet; but it is hard, and makes a very good roof. The Mahoning sandstone is shown in the hill above this pit.

Within one fourth of a mile from this opening, the railroad crosses a deep gorge, in which the coal bed is exposed below the track with several feet of shale between it and the Mahoning sandstone, which forms a bluff on each side of the gorge. The thickness of the shale varies abruptly, and the limits seem to be as given above. From this ravine, the coal rises until at Austin station it is above the track, and at half a mile further it is mined and coked by the Austin Mining Company.

The outcrop of the bed is easily followed southward from the railroad, and lies at but a little way eastward from the ridge-road leading from Tunnelton to the Northwestern turnpike. The coal is reached at that pike. Few of the ravines thus far are deep enough to expose the coal, but that through which Sandy creek runs affords good exposures, and the bed had been opened at several places along that stream.

Beyond the point where the ridge road reaches the pike, at say five miles from Tunnelton, the ravines become deeper and exposures of the bed are numerous. Pits were seen on several farms. In this direction, the bed becomes thicker though it seems hardly to improve in quality. One opening, seen on Mr. Wolf's farm at about eight miles from Tunnelton, shows 11

feet of coal without any persistent parting, though there are many insignificant partings which continue for but a few yards. The coal appears to be more sulphurous here than it is nearer the railroad, and the ash is greater.

The bed was followed northward from the railroad for several miles, but its structure there is similar to that seen in the pits on the railroad.

The dip throughout is north-westward, and the undulations with respect to the track are due to curves in the railroad.

The especial feature of the bed here, aside from its thickness, is its freedom from sulphur. In the Ligonier valley of Pennsylvania, according to Mr. McCreath's analyses, the sulphur in *Upper Freeport coal* varies from 1.414 to 4.789, and the coal rarely yields a firm coke. The ash varies from 3 to 6 per cent. Further south, in Upshur and Randolph counties of West Virginia,* the sulphur is high, and the ash is considerable even when the coal is best.

Within the area immediately under consideration, the coal from this bed yields an excellent coke. The Austin Company has found a ready market for its product, which in Chicago competes on even terms with the Connellsville coke. Several car loads of coal from the vicinity of Tunnelton were sent to Connellsville and there coked. Two lots were sent to the Cambria Iron Works, where analyses were made by Mr. Morrell with the following results:

Car No. 1, made from *sound coal:*

Carbon	92.64
Sulphur	0.53
Ash	6.82

Car No. 2, made from *outcrop coal:*

Carbon	88.05
Sulphur	1.41
Ash	10.54

Coke made from coal obtained at another opening was sent to the Edgar Thompson Steel Works, where it was analysed by Mr. S. A. Ford, with the following results:

Fixed carbon	88.163
Volatile matter	0.875
Sulphur	0.837
Ash	10.125

These tests seem to have been sufficiently extensive to determine the value of the coal for coking purposes. The loss in coking, as reported by Mr. M. L. Schaefer, Superintendent of the Austin Company, is about 33 per cent, indicating a composition very nearly like that of the *Pittsburgh coal bed* in the Connellsville basin.

*For description of the bed in these counties, see *Notes on the Geology of West Virginia*, by the writer, read before this Society on February 5, 1875.

It is evident then that the *Upper Freeport coal bed* in this region will yield a coke which is not appreciably inferior to that made at Connellsville, Pennsylvania.

Few details were gathered respecting the general section exposed along the slope of Laurel ridge, as all detailed work was stopped by a severe snow storm. A bed of cannel was seen at not far from 165 feet above the *Upper Freeport*. On one side of Sandy creek, this bed shows 4′ 8″ of cannel, but on the other side of that creek it shows no cannel, and contains only bituminous coal, 3′ 6″ to 4′ thick. The cannel was worked many years ago for distillation of oil, but the works were abandoned on the discovery of petroleum.

The Freeport limestone is present at from 40 to 50 feet below the *Upper Freeport coal bed*, and is exposed at one locality nearly three miles north from the railroad. It is 3 feet thick, and rests on a bed of iron ore, which is 30 inches thick and very persistent. This ore was mined at one time both by benching and drifting, and the material was sent to the Irontown furnace, where it produced a foundry iron. It is too cold-short for use alone, and to be available must be mixed with some ore containing little or no phosphorus. A small coal bed rests on the limestone, and another, about 2 feet thick, is shown at nearly 70 feet lower.

Memoir of S. S. Haldeman, A. M., Ph. D., etc. By D. G. Brinton, M. D.

(*Read before the American Philosophical Society, February* 4, 1881.)

In presenting a sketch of the life of the late Professor Haldeman, I shall begin with his personal history, and then proceed to give a brief account of his contributions to science.

Samuel Stehman Haldeman was born August 12, 1812, at Locust Grove, a beautifully situated country-seat on the east bank of the Susquehanna river, twenty miles below Harrisburg. The house, with the extensive property surrounding it, had been in the possession of his ancestors for several generations.

The family came originally from Thun, in German Switzerland, and were an energetic, independent race, who had been honored in their day. Jacob Haldeman, a great-grandfather of the subject of this memoir, was chosen one of a Committee of Public Safety from Rapho township, Pa., in revolutionary times. Frederick Haldimand, a great-uncle who had entered the English military service, became first Governor-General of Canada under that rule. John B. Haldeman, a grandfather, was member of the General Assembly from Lancaster county, in 1795. The name was formerly spelled with either *i* or *e* in the second syllable and the final *d* rejected or retained according to the language of the canton in which it was found, but as it was of Germanic origin, Prof. Haldeman always used the German method.

He was the oldest of seven sons, his parents being Henry Haldeman (1787–1849) and Frances Stehman (1794–1826). His father, a lover of books, endeavored to foster in this, his favorite child, a desire for learning, and to impress upon him its importance. His mother, a lady of attainments, dying when he was but twelve years old, had but little influence upon his after career, except perhaps that his great accuracy in detecting and analyzing unusual sounds in language may have been inherited from her who was an accomplished musician. His early education was pursued at the local schools, supplemented by a good library at home. The favorable opportunities for the observation of nature which presented themselves he improved by forming a boyish museum containing rude anatomical preparations made from rabbits, opossums, muskrats, etc., and of birds, which a traveling Methodist preacher had taught him how to stuff. An extract from a letter to a friend, dated 1844, contains these words, "I collected shells on the banks of the Susquehanna long before I knew the meaning of genus and species."

In the spring of 1826, when nearly fourteen years of age, Mr. Haldeman was sent to the Classical Academy of Dr. John H. Keagy, at Harrisburg, Pa., a gentleman of whom he always spoke as being an able thinker and thorough scholar. An assistant teacher, Mr. J. T. Q. Mittag, who is yet living at an advanced age, refers with enthusiasm to the precocity and studious habits of his pupil at that time.

He remained at Harrisburg two years, and then went to Dickinson College, Carlisle, Pa., where his taste for natural science was encouraged by Prof. H. D. Rogers, subsequently the distinguished geologist. But his early freedom and the bent of his own sturdy genius made the restraints of a college course irksome, and after two years he left Carlisle without waiting to obtain a degree and with the intention of pursuing his studies alone. In fact, the lack of thorough teaching in his youth had given him a rooted distrust for the opinions of the masses, and had formed habits of self-reliance which forced him to be original or nothing. "I cannot learn from others, I must see for myself," he would impatiently exclaim, and thereupon would proceed to investigate an assertion with a series of cross-examinations such as were well calculated to develop the exact truth. In after years, to see some poor native under the fire of his questions, when the pronunciation of an *a* or an *u* was at stake, was almost painful. His horror of compilers was such that once when returning from Europe, being reproached for having written such short letters "when seeing so much to write about," he characteristically referred the speaker to an excellent work on European travel, saying that as everything had been well described there, it was not worth while to repeat it.

Thus at the age of eighteen he began to direct his own studies and to accumulate at the paternal mansion cabinets of geology, conchology, entomology, botany and a scientific and linguistic library. As the bias of local opinion rendered it necessary that all young men who were not professional should go into business, he assisted his father in conducting a saw-mill on

a newly acquired property, called at that time Chickiswalungo. The young student found business even more tedious than college routine, and relates of himself at this time, "I developed a taste for rainy weather and impassable roads; then I could remain undisturbed in the perusal of my books, a supply of which I kept in a back office, where I retired as soon as the sky looked threatening." This taste for rainy days was not fictitious and remained with him during his life.

In 1835, Mr. Haldeman married Miss Mary A. Hough, a lady whose eminent qualities and devotion to his interests greatly aided to render his after success possible. Ably taking upon herself those cares which a growing family entail, she left him leisure for the pursuit of his favorite projects, and it was in consequence of her wish that he wrote his essay on *Analytical Orthography*, which, though not more important than his other works, gained him an European reputation.

Shortly after his marriage, Mr. Haldeman, with his wife, occupied the residence built for him by his father at Chickies, and became a silent partner in the iron business conducted by his brothers, Dr. Edwin and Paris Haldeman. Here books and cabinets accumulated under his laborious hands, only to be scattered again and give place to others when his insatiable appetite for knowledge led him into new fields of investigation. For forty-five years he spent most of his time in his library, where in his vigorous manhood he worked sixteen hours a day. For though he accepted several professorships and delivered a number of courses of lectures, he did so with reluctance, preferring to be master of his time and to spend it in the quiet of home.

In person, Mr. Haldeman was of middle height, with small, well formed hands and feet, a large and remarkably round head, giving great breadth across from ear to ear; high forehead, Roman nose, full lips, black eyes, and in youth a quantity of black hair, which at his death was of snowy whiteness. Long before it was usual in America he wore a moustache and beard, not for adornment but for convenience. In speaking, he had a clear enunciation, penetrating voice, and much readiness at repartee. His movements were rapid, his disposition cheerful, his general health excellent, and his interest in science unflagging to the end of his life, his latest occupation for leisure moments being the forming of an archæological collection, in which he took great pleasure, and the advancement of the spelling reform.

His death took place suddenly at seven o'clock, Friday evening, September 10, 1880. On returning from the meeting of the American Association for the Advancement of Science, held at Boston, August 23d, he complained of fatigue, but insisted on occupying his library as usual. A physician being sent for advised rest, but it was only on Friday morning that he could be induced to keep his bed. The physician paid him a long visit on Friday afternoon, and Mr. Haldeman conversed cheerfully for about an hour; only once he complained of weakness, and fixing his eyes on the doctor, asked, "Do you think this could be the breaking up of my sys-

tem?" but seemed satisfied when the doctor, surprised, answered "No." A few hours afterward, having risen from his bed without assistance, his son, who was in the next room, heard a fall; in a moment he was by his side and had taken him in his arms, but though every means was resorted to that animation might be restored, life had departed. Death was occasioned by a disease of the heart, to which he had some hereditary predisposition.

I may add to the above some personal reminiscences illustrating Prof. Haldeman's character, communicated to me by Prof. E. A. Barber, of this city.

Like most men of high impulse and native truthfulness, it was difficult for him to suspect deceit in others. On one occasion he showed Prof. Barber a small stone ornament shaped like a fish, and enthusiastically described it as one of the "finds" in the famous "Chickies rock retreat." With some hesitation his auditor pointed out certain suspicious marks about it, and suggested the possibility that it had been manufactured by one of the boys engaged in the excavation. For the first time the idea of such an imposition crossed his mind, and further investigation led to a confession of the act by the perpetrator.

It was his taste and apparently also his theory that a student should not be a specialist, but should devote his mind to different branches, thus securing wider knowledge. In a conversation with Prof. Barber, he once said: "I never pursue one branch of science more than ten years, but lay it aside and go into new fields."

As a correspondent, he wrote frequent letters, but brief ones, and generally was an enemy to prolixity. In one of his letters he writes, "You may think the enclosure rather short, but I dislike palaver, and like to say my say, then stop."

This trait shows itself in his writings. His style is terse and nervous, and his matter shows constant evidence of careful arrangement, so as to secure the utmost condensation compatible with clearness.

Professor Haldeman's religious views were fixed for many years before his death. Born of Protestant parentage, he was led in early life to doubt the theology which he heard taught in the schools and preached in the pulpits of Central Pennsylvania, and for a term of years did not attach himself to any sect or church. Later on he took up the systematic study of the evidences of religion, convinced that this is a subject on which every man of intelligence should have definite and defensible convictions. The result of his studies was that he united himself with the Roman Catholic Church, which he stated he had found to be the earliest historic form of Christianity, and he remained a consistent member of that confession until his death.

Early distinguished as a devoted student of natural science, Prof. Haldeman was selected to fill various public positions as an expert and a teacher. In 1836 he was chosen an assistant in the New Jersey Geological Survey, and the following year held a similar office in Pennsylvania, and

prepared a work on the geology of that part of this State lying between the Blue mountain and South mountain, from the Delaware to the Maryland line, which was published May 1st, 1837. While engaged in this occupation he discovered the *Scolithus linearis*, the oldest fossil then known. In 1851 he became Professor of Natural History in the University of Pennsylvania; in 1855, in Delaware College, acting also as Professor of Geology and Chemistry to the State Agricultural College, and subsequently became Professor of Comparative Philology in the first-named institution, when that chair was first established, and filled it continuously up to the time of his death.

Turning now to his record as an author, we find Professor Haldeman displayed amazing activity in a variety of branches. In his earlier years natural history was his passion, while in his later life linguistics and archæology occupied most of his attention.

The first work which I can find assigned to him was "Fresh Water Univalve Mollusca," published in 1840, 2 vols., 8vo, which is now out of print. This book is very scarce and it is difficult to obtain a copy, the last one that was sold bringing thirty dollars; in 1842 he published "Zoological Contributions;" in 1847 he issued a work on the "Genus Leptoxis," in French, while on a visit to Paris. It is part of the *Illustrations Conchologiques* of Dr. Chenu. In 1849 he issued his first philological work, entitled "Some Points in Linguistic Ethnology," dealing with English languages, and from that date he became recognized in the scientific world as one of the leading philologists.

In 1850 he published a work, "Zoology of the Invertebrate Animals;" in 1851, "Elements of Latin Pronunciation;" in 1855 he edited "Taylor's Statistics of Coal;" in 1856, a work on the "Relations of the English and Chinese Languages;" in 1864 he issued a work on the game of chess under the title of "Tours of a Chess Knight;" and in 1868, the "Rhymes of the Poets," under the *nom de plume* of "Felix Ago;" in 1871 he issued a work on "Affixes to English Words," and in 1877, his last work, entitled "Outlines of Etymology," was published.

The Professor leaves behind him a complete work on "Word Building," which is designed for the use of classes in Etymology, and which is ready for the printer; also a work on "English Prosody." He also leaves the manuscript of "Rat and River—a Tale of the Ohio," a mock heroic poem, and a poem of the same kind entitled, "Flight of the Fishes."

In addition to these works he has contributed probably one hundred and fifty papers on various scientific subjects, especially relating to Geology, Conchology, Entomology, Philology, and several branches of Zoology, which have been published in the Proceedings of the American Association for the Advancement of Science, the American Philosophical Society, American Philological Association, Academy of Natural Sciences, and many other learned societies of which he was a member. This Society is now publishing in their Transactions a monograph on "Contents of a Rock Retreat in Southeastern Pennsylvania," which is descriptive of the

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Indian arrow heads and other relics found in the cave under Chickies rock. He was the first editor of the Pennsylvania "Farmers' Journal," a contributor to "Silliman's Journal," the "Iconographic Encyclopædia," the "Literary World," and Johnson's Cyclopædia.

Of the latter he was also an associate editor of the Comparative Philology and Linguistic department, and was the author of numerous articles in it. He also wrote two or three manuals of orthography, pronunciation and etymology, and his treatise on "Analytical Orthography," consisting of investigations into the philosophy of language, gained him, in 1858, the highest Trevelyan prize over eighteen competitors. He wrote the zoological portion of Trego's "Geography of Pennsylvania" (1843), and Rupp's "History of Lancaster County" (1844).

I have endeavored, without success, to prepare a complete list of these numerous papers, and must content myself with the above general references to them.

In conclusion, I wish to present an appreciative tribute to Prof. Haldeman's scientific attainments from the pen of his personal friend and our much esteemed member, Dr. John L. LeConte.

"Next to his valuable contributions in Philology, the most important work of Prof. Haldeman was in the direction of descriptive Natural History. He was well versed in several branches of Zoology, and notably in Conchology and Entomology; in both studies he perceived latent possibilities of future philosophical development, which the then imperfect observations rendered impossible to do more than dimly outline. This quality is especially noticeable in remarks scattered through his monograph of Fresh Water Univalves of the United States, and in a memoir;* 'Enumeration of the recent fresh water Mollusca, which are common to North America and Europe, with observations on species and their distribution.'

"Without being a partisan, any more than myself, in the scientific squabble which then provoked much bitterness of expression between the contending factions, but which has since dwindled into comparative insignificance —the single or multiple origin of man—we held frequent conferences upon the subject. And in these friendly talks, I have heard him express himself freely on the impossibility of the results of the naturalist (now the biologist), being ever acceptable to the adherents of the scholastic school, 'For,' said he, 'if it be proved that organic forms are invariable during their continuance upon earth, then the different human races must be considered as having originated independently. If on the other hand, organic forms are plastic, under circumstances not yet understood, then the present species may have been developed from species which preceded them, and have not resulted from direct creative acts. Either horn of the dilemma is unsatisfactory to the metaphysical views prevalent.'

"While his contributions to the two branches of Zoology above mentioned have contributed to their advance in this country, what are especially to be admired are the zeal, the honesty of expression, and the unselfishness

*Boston Journal of Natural History, vol. iv, p. 468.

with which he did everything he believed to be right, or to be his duty as the occasion dictated.

"When in affluence, his contributions for the promotion of science were liberal. When in moderate circumstances, he pursued with equal industry such subjects in science as required small expenditure. But at all times he was an industrious and intelligent laborer, a warm and sympathetic friend, and a thorough hater of pretence and empiricism.

"Failing eyesight compelled him eventually to give up his studies in Zoology, and to devote his whole time to Linguistics, for which he had exhibited a growing taste for several previous years.

"The rare flexibility of his vocal organs gave him peculiar facility for analyzing and imitating the sounds in foreign languages, which he never lost any opportunity of hearing in his travels, both in this country and in Europe. In this matter his Natural History training in accurate observation, aided by remarkable perceptive qualities, gave him great advantage, and I am convinced that his analysis of the causes of change of sound in words, in passing from one language to another, will hereafter receive much more attention than they have heretofore done in this, the country of his birth, where such investigations are still in their infancy."

Stated Meeting, February 18, 1881.

Present, 12 members.

President, Mr. FRALEY, in the Chair.

A letter acknowledging Diploma was received from A. Akerman, dated Stockholm, Jan. 16, 1881.

A letter requesting missing numbers of the Proceedings was received from the Rhode Island Historical Society, February 14, 1881.

A letter respecting the third part of Transactions, Vol. XV, was received from E. A. Barber, 4008 Walnut street, Philadelphia, February 14, 1881.

Letters of acknowledgment were read.

Donations for the Library were received from the Mining Surveyors at Melbourne; the Zoologischer Anzeiger; the Academia dei Lincei; the Academy at Brussels; M. Delesse; the Revue Politique; London Nature; Journal of Forestry; Mr. T. S. Brown, of Montreal; Essex Institute; Poughkeepsie Society of Natural History; Mr. B. A. Hinsdale; Penna.

Magazine of History; Franklin Institute; Medical News; Mr. T. Meehan; Mr. H. Phillips, Jr.; Naturalist's Leisure Hour; State Board of Agriculture; Johns Hopkins University; Lighthouse Board; American Antiquarian Society; Wisconsin Historical Society; Robert Peter, M.D., and the Asiatic Society of Japan.

The death of the Rev. E. A. Washburn, D.D., at New York, February 2, 1881, aged 58 years, was announced by the Secretary.

The death of Auguste Mariette Pasha, at Cairo, Jan. 19 aged 60 years, was announced by Mr. Lesley, with a sketch of his career as an Egyptologist.

A communication was read, entitled "On the course of Fossil Botany," by Prof. M. B. Renouf, at Paris, by Leo Lesquereux.

A copy of the original photograph of the nebula in Orion was presented by Dr. H. Draper.

A communication was read, entitled "On certain old Almanacs published in Philadelphia between 1705 and 1744," by Henry Phillips, Jr.

The minutes of the last meeting of the Board of Officers and Members in Council were read. On motion the action of the Board in disposing of certain old newspapers by presentation to the Pennsylvania Historical Society was approved.

The following report of the Chairman of the Committee on the Michaux Legacy was read, as follows:

Report of the Chairman of the Committee on the Michaux Legacy:

Half of the income of the legacy for the last year was duly paid over by the Treasurer to the Treasurer of the Fairmount Park Commissioners, and has been duly applied to the cultivation and distribution of trees, partly in Park planting and partly to others.

The other half was not all spent because Professor Rothrock only delivered a half course of seven lectures in the Park, as he desired to go and went in the early summer to Strasburg to perfect himself in German, and to pursue his botanical studies under Professor De Barry. There was an increased attendance and interest in Dr. Rothrock's last spring's lectures.

Owing to but a dividend of 33 per cent. having been received for the Auxiliary Faculty by the University from Dr. Wood's estate, Dr. Roth-

rock will have but one-third his usual income from that chair. It is important that we keep him in Philadelphia. I therefore recommend an appropriation of $330 for a course of fourteen lectures in the Park.

The year 1880 was most abundant in tree seed, and they were gathered in quantities much greater than ever before and in more varieties. We have planted the Hardy Catalpa in large quantity and have the seed for planting this spring; also the seeds of the White Cedar, both very valuable for enduring wood.

ELI K. PRICE, *Chairman, &c.*

It was, on motion,

Resolved, That $330 be appropriated for the Michaux lectures.

On motion it was resolved that the whole subject of stereotyping and printing separately the publications of the Society for convenience in meeting such requests as that of Mr. Barber, in his letter of the 4th inst., be referred to the Committee on Publication, with the Treasurer, to report.

New nominations Nos. 928 to 931 were read.

And the meeting was adjourned.

On a Cours de Botanique Fossile by Prof. M. B. Renault.
By Leo Lesquereux.

(*Read before the American Philosophical Society, February* 18, 1881.)

In this course of lectures given by Prof. Renault in the museum of natural history of Paris, the author gives very interesting details on the results he has obtained from anatomical analysis of silicified specimens of fossil plants. The volume recently published exposes the characters of a single group, the *Cicadeæ*, which the celebrated phyto-paleontologist has followed in all their subdivisions and modifications from the present age to the Devonian. These researches throw some new light on the nature or internal structure of some plants of the coal measures, especially the *Cordaites*, the *Sigillariæ* and *Stigmariæ*.

Prof. Renault divides the *Cicadeæ*, from the structure of the wood, trunks and leaves, in five groups or families, which from a difference in the essential characters of the wood he subdivides in two sections, A. B.

The plants are composed of vascular vessels forming two juxtaposed woody parts inversely increasing the one toward the centre (centripetal), the other toward the outside (centrifugal). This double increase is going on in both the leaves and the stems. To section A are referable the *Cicadeæ*, the *Zamiæ*, the *Cicadoxylæ*, and the *Cordaites*, to B the *Poroxylæ* and the *Sigillariæ* with the *Stigmariæ*.

The *Cordaites* and the *Sigillariæ* being now well known from American

specimens, are the only of these families which are interesting to the botanical paleontology of this country.

For the *Cordaites*, Prof. Renault has given very detailed anatomical descriptions and splendid illustrations of all the organs of these plants, as complete indeed as if they had been made from living vegetables. The development of the plants is followed from the fertilization of the ovule; for grains of pollen have been discovered, by vertically cutting the embryonic bodies, one already enclosed into the pollinic chamber, two of them still on their way downward in the pollinic tube.

The first of these grains is fully ripe, as recognized by the author, who has been enabled to see a difference in the mode of fertilization from the difference of size and structure of the grains of pollen which were as profusely disseminated around, at the Carboniferous epoch, as are those of the Conifers at our time. When found in a state of dissemination, the grains of pollen of the *Cordaites* are already a third larger than those still fixed to the anthers, and they appear then composed of an internal globule (entine), and of an outside envelope (extine). On the grains still placed in the pollinic tube, the fertilizing globule is more distinct, and more distinctly separated from the envelope, while the grain placed in the pollinic chamber is still larger, and its two parts more distinct. It seems therefore, according to the remarks of the author, that in their exit from the anthers, the pollinic grains are not fully ripe or prepared for the act of fecundation, and that they have need of a second process of evolution, while enclosed in the pollinic chamber, for a full separation of the cells and the completion of the fertilizing action. This process differs from what is remarked in the plants of the present time, by the fact only, that now the pollinic grain is already perfect, when it becomes detached from the anther, and is not surrounded by a membrane.

The wood of the trunks of *Cordaites* is composed of a thick pith or medullary cylinder, which is generally known under the name of *Artisia* or *Sternbergia*. The medullar cylinder very variable in thickness is obscurely costate lengthwise and transversely marked by close parallel furrows, sometimes anastomosing with each other. These furrows are formed, as seen from the anatomical analysis of silicified branches, by medullary transversal bands, which in the living plants, produced a division of the medial cylinder into as many empty excavations, each corresponding, by contraction of the surface, to an outside furrow.

The wood itself is formed in its inside part, or in contact with the medullary axis, of two zones; the inside of the first is composed of annulate and spiral trachids, its outside of radiate and reticulate ones separated by the medullary rays. The trachids of this last zone gradually pass, by the enlarging of the striæ of their walls, into punctate trachids, which constitute a second woody zone, which is of considerable thickness in large trunks, and always composed of trachids with areolate perforations, disposed in radiating striæ, and separated also by medullary rays. The areoles are in contact; by mutual compression they become hexagonal, and are pierced

in the centre by small pores or inclined fissures, which, by contraction or widening, become elliptical or round. In badly preserved or old specimens the pores occupy nearly the whole space of the areoles.

The characters of the wood of *Cordaites* as exposed above are much like those of the wood of some Conifers, and from this affinity, the fossil fragments of wood or trunks discovered in the Devonian and the Carboniferous, have been generally referred by authors to Conifers. *Dadoxylon* Endl., *Araucarites* Gœpp., *Pinites* Lind. and Hutt. are all referable to *Cordaites*. It is now well known that *Lomatophloios*, to which Corda referred the medullary cylinder of *Artisia*, has a far different kind of pith.

Considering especially the structure of the trunks of *Cordaites* and the character of the fructifications, Prof. Renault finds a relation between these plants and the *Cycadeæ*, from which they greatly differ, however, by their mode of growth and stature. The disposition of the flowers has some analogy with that of the *Taxineæ* or *Genetaceæ*.

The *Poroxyleæ* do not offer any remark applicable to what is known of fossil plants of this continent. They are represented by fossil trunks, of which three species are described by the author.

The *Sigillariæ* and the *Stigmariæ*, on the contrary, are of peculiar interest on account of the great abundance of their remains disseminated over and in the whole thickness of the American Coal measures, sometimes constituting whole strata of combustible mineral.

Prof. Renault finds, in the wood of *Sigillariæ*, medullary rays, an endogenous and an exogenous zone, and vasculur fascicles originating between the zones and constituting the strings of vessels entering and composing the leaves. These characters relate them to phanogamous gymnosperms.

From anatomical researches, Brongniart had come to the same conclusion, which is supported also by Saporta and Grand 'Eury. On the contrary Profs. Hooker, Williamson, Binney of England, who have pursued repeated observations and made numerous and very careful anatomical analysis of the wood of *Sigillariæ*, find in it the characters of Lycopodiaceous plants, and relate them to *Lepidodendron*.

The discordance of views may result, as supposed by Prof. Renault, from the difference of age of the plants from which were derived the specimens subjected to analysis. But the supposition is strongly contradicted by Prof. Williamson in a recently published paper, on the organization of the Fossil Plants of the Coal measures.* To follow the details of the discussion on this very interesting question it would be necessary to have the illustrations under the eyes.

We have no means of comparing the determination of the celebrated authors. All that I know and can see from American specimens of the outside characters of *Lepidodendron* and *Sigillaria* indicates a close typical relation of both genera, and therefore in the U. S. coal flora I have placed the genus *Sigillaria* in the *Lycopodiaceæ*.

Stigmaria necessarily follow *Sigillaria;* for remains of *Stigmaria* have

* Proc. of the Royal Soc., No. 205, 1880.

been found attached to trunks of *Sigillaria* as roots. From this fact Stigmaria plants have been generally admitted as true roots and are so in certain circumstances.

On this subject Prof. Williamson says, that *Stigmaria* belongs alike to *Lepidodendron* and to *Sigillaria* as root. I have never seen any positive relation of these two genera of plants, or never found any remains of *Stigmaria* in connection with those of Lepidodendron. Even in what seems to be a creeping state, or rooting like that of some Lycopods, the small intertexted stems of *Lepidodendron* exactly preserve the peculiar form of their leaf-scars and never have round areoles like *Stigmaria*.

What was known formerly of the structure of these plants by the anatomical analysis of phytopaleontologists is confirmed by the researches of Prof. Renault. However, from the mode of life of the *Stigmariæ* which in certain cases and for long periods of time appear to have had an independent vegetation, he supposes that these plants are of two kinds; some roots, others rhizomas.

In transversal section of *Stigmaria ficoides*, he has observed as obliquely traversing the woody cylinders two kinds of vascular fascicles, the first numerous, reaching to the outside, true vascular bundles of leaves; the others less numerous in the interior of the wood, which represent fascicles of roots. Hence in certain circumstances *Stigmaria* plants bear leaves; in others, fascicles of roots may be developed.

I have already at different times exposed my views on the variable nature of these plants according to their mode of vegetation. They have been more recently resumed in the description of the genus *Stigmaria*, Coal Flora of Pennsylvania and the United States, 1881, page 500, &c., and I think that they agree in all essential points with the opinion of the French author. *Stigmariæ* as stems (or rhizomas) have lived independently and for long periods of time floating at the surface of the swamps of the Carboniferous, or covering the soft mud, without producing any fructifications. In this case the stems, horizontal, rarely branching (dichotomous), preserve a uniform size, and bear also tubulous leaves only, more or less regularly disposed in spiral, no rootlets. Wide surfaces of rocks are covered with plants of this kind, and thick strata of clay are filled or composed of their remains, without any fragments or traces of *Sigillaria*. This vegetation may be called adventive. But in another case the germinating process may begin on sand or on a floating carpet of stems of *Stigmaria*, having become compact and solid enough to support trees. Then the growth of the plant from the production of a vertical bud proceeds upward and downward, and the basilar appendages, first obliquely inclined downward, become gradually more or less vertical as true roots and bear rootlets, often still mixed with leaves, as seen by their scars of different size and conformation. This kind of vegetation finds an analogy in that of a number of floating plants of our time: Mosses, Lycopods, etc.*

* Grand 'Eury has lately, in exploring the coal fields of Germany, recognized these two distinct modes of vegetation of the *Stigmaria*.

The work of Prof. Renault is closed by remarks on the geological distribution of the plants of the families which he has examined.

The *Cicadæ* appear in the Carboniferous by *Pterophyllum carbonarium* and persist through the more recent formations to our time.

The *Zamiæ* have also a carboniferous species *Nœggerathia foliosa*, and a few others in the Jurassic.

The *Cycadoxylæ* are represented by fossil wood of the upper Carboniferous.

The *Cordaites*, the *Poroxylæ* and *Sigillariæ* are all Carboniferous and Devonian; a few ascending to the base of the Permian.

Certain Almanacs Published in Philadelphia between 1705 *and* 1744.

By Henry Phillips, Jr.

(*Read before the American Philosophical Society, February* 18, 1881.)

In the library of our Society is a volume of Almanacs printed and published in Philadelphia, at various dates between 1705 and 1744.

They are remarkable specimens of the degree of perfection, or rather lack of perfection, to which the art of printing had attained in the Middle Colonies in those early days, beginning with extremely bad paper, blurred impressions and imperfect type, and exhibiting a progressive improvement towards the later dates, but nowhere showing, however, what now-a-days would be called a good piece of work.

The volume which is a duodecimo, consists of Jacob Taylor's Almanacs for 1705, 1706, 1709, 1711, 1712, 1719, 1720, 1723, 1727, 1738, 1740, 1741, 1743, 1744, and Titan Leed's Almanac for 1718.

As a curiosity I reproduce the title page of Taylor's Almanac for 1705, which will serve as a fair specimen of the manner in which publishers of that era were wont to attract the attention of the purchasing community.

An ALMANACK *for the year* 1705. | AN | EPHEMERIS | of the Motions and ASPECTS of the | PLANETS | and the *Eclipses* of the *Luminaries* for the *Year* | of *English* account 1705 | Fitted to the latitude of 40 Degrees North, and | the Longitude of 75 Degrees West of *London;* | serving *Pensilvania* and the Places adjacent. | By JACOB TAYLOR. | *Hermes Trismegistus.* Centiloq. Aphor. 33 | . *Saturn Passing out of one sign into another causes strange Appari* | *tions in the* Heavens *which the Arabians term* Asiub; & *Cer* | *tain other signs of a fiery nature.* | To which is added by C. P. some remarks on D. L's abuses | to the *Quakers*, in his this *Years* two ALMANACKS. | Printed at *Philadelphia* by Tiberius Johnson. | .

This Almanac is a small volume of sixteen leaves, pages unnumbered and without signatures.

On the recto of the title page is a "Table of the KINGS of *England*, shewing the Years wherein They began to Reign; the Years which they have Reigned, and the Years since they Reigned."

The second leaf is occupied by a piece of terrible poetry, most shockingly printed, in which is depicted the difficulty

"To please all Humors suit all sorts of men,"

and concluding with the lines,

"To them that shall presume that Risque to run,
To let us know how were imposed on,
Detraction, envy, slander shall accure (qy accrue?)
From that ill natured, vaunting, lying Artless Crue."

The last word is so badly printed as to be almost illegible.

The page following contains an explanation of the Almanac, and the characters and signs.

The next page sets forth the eclipses for 1705.

On the next page occurs "XI month JANUA. *Cæteris mensibus,*" below which is the usual calendar with weather predictions.

On the subsequent page is a table of the motions of the planets, beneath a heading "The Eleventh *Month* 1705," and followed by remarks on the Conjunction of Saturn and Mars set down for the month.

On the next page is "The XII Month FEBRUATIO *Romanorum,*" and beneath are the usual calculations and weather predictions. On the left hand pages the months continue, ending with DECEMBER, *Decimus Mensis.* On almost every right hand page there is a piece of poetry relating to the supposed influences of the starry bodies and their motions, as to the passage of the seasons. Under August, we find

"But *Leeds* exerts a Thumping Wit
Above all vulgar measure,
Moves Nature in a jumping fit,
According to his pleasure;

Transcribing was the Art he us'd
'Twas all the skill he had,
But being of the same Accus'd
It almost made him M—D."

On the last three pages the author falls foul of Daniel Leeds, a rival Almanac maker, charging him with having stolen from Gadbury's Ephemeris and also from a little work by Jacob Taylor, entitled Eclipses of the Sun and Moon for twenty years. The attack is characterized by all the personalities and indecorum which were usual among our free spoken ancestors.

The first printing office in Pennsylvania was established about 1686, by William Bradford, and the earliest productions of this Press were Almanacs for the years 1686 and 1687. (Thomas, History of Printing, Vol. i, p. 209.)

The name of Jacob Taylor appears as that of a printer, who "was in town" in 1712, but Thomas states that he never met with anything that bore his imprint, and entertains doubts as to whether he was actually a printer. He says, "There was a Jacob Taylor, who for about thirty years annually calculated an Almanac, which was published in Philadel-

phia by Andrew Bradford ; he was probably the same person ; he died in 1746."

Thomas (Vol. i, p. 223) does not mention the existence of a printer named *Tiberius Johnson*, the person who printed this Almanac, but states that a certain *Renier Jansen* managed the press of William Bradford in Philadelphia from the time of his removal to New York until his son Andrew came of age.

Mr. John William Wallace, who has an especial knowledge of all things relating to early Pennsylvania printing, informs me that Tiberius Johnson was a son of Renier Jansen, whose name easily passed from and through the form of Jansen to Johnson, but he states that this Tiberius Johnson "so far as being an actual printer, or indeed a person having even a theoretical knowledge of typography * * * is a revelation" to him. That he never before heard of any imprint by him, and that the fact that he ever did make one has been generally unknown. This little volume, which bears his imprint, therefore appears to be unique.

It is therefore probable that Tiberius Johnson continued to nurse the business till Andrew took it. The Jacob Taylor Almanac for 1706 was "printed for the author ;" that of 1709, bears no imprint at all ; 1711 and 1712, are "printed at Philadelphia." The Almanac of Jacob Taylor of 1719 bears the imprint of Andrew Bradford.

The Almanac issued by "Titan Leeds, Philomat" bears title "The *American* Almanac for the year * * * * * 1718 * * * Printed and Sold by Andrew Bradford at the sign of the Bible in Philadelphia."

It is likewise a small duodecimo of twelve leaves, lacking signatures and unnumbered.

On the *recto* of the title is an address to the "*Curteous Reader*" in which occurs the following passage ;

"*Note.* That whereas my Preface, Last year gave Account that at least one Third of the Inhabitants of *West Jersey* were of the People called *Quakers*, but in my Copy I had written that there was not one third Quakers."

I Believe I may Venture,
To say this I do take,
For a wilfull mistake ;
Of My Printer.'"

The usual figure of "The Anatomy of *Man's Body* as govern'd by the 12 Constellations" appears on the leaf following the title page, and is a most execrable work of art, shockingly engraved.

The astronomical calculations in the body of the Almanac are interspersed of pithy sayings of more or less point ; such as, "Land winds are coldest, so sea winds are warmest," "He is sober who is never drunk with anything but wine," "The old woman would not seek her daughter in the oven if she had not been there herself," "Oft under honey sweet poison lurks," "March dust to be sold worth Ransom of Gold," "An evil crow an evil egg ;" "Beware of a Smooth Devil ;" "Scotch mist wets Englishmen to the Skin ;" "So many planets joined together denote some Thun-

dring weather;" "Passion runs through all languages." "Proceed, but do justice;" "It is a bad Devil that does no good."

Above the calculations for each month is a piece of six lined poetry of moral and didactic nature.

In January it runs thus:

> Old Janers still begins the rouling Year,
> And all that's past no vows can e'er restore" * * *;

in December:

> "Death is a kalendar composed by Fate,
> Concerning all men, never out of Date." * * * * * *

It gives also a list of eclipses and the Date of holding "Supream Courts in *Pensilvania.*

At *Philadelphia* the tenth day of *April* and the 24 Day of *September.*

Courts of Quarter Sessions in *Pensilvania.* At *Philadelphia,* the first Monday in *March, June, September,* and *December.* * * *

Courts of Common Pleas are held: At *Philadelphia,* the first Wednesday after the Court of Quarter Sessions * *.

Then follow the terms of the *Supream* Courts and Courts of Common Pleas in New York, and the Supream Courts and Courts of Quarter Sessions in New Jersey, and at the end is a calendar of Court Days for Maryland.

Taylor's Almanac for 1719 was printed and sold by "Andrew Bradford in the Second Street near the great meeting House, in Philadelphia, 1719."

It is a small duodecimo of fifteen leaves, in signatures lettered respectively, A, B, C and D.

The compiler is honest enough to state, in the beginning, that "the Sentences on the Heads of the Monthly Pages are mostly borrowed."

Among the most noteworthy are the following:

"From the first Hour of the Day (or one in the morning inclusive) till six B good predominates, whence morning sleep becomes so sweet and pleasant, from thence to Noon, Choler, Afternoon, Phlegm, from the Beginning of the Night till Midnight, Melancholy."

"Near to St. Omer's in Flanders is a large Lake in which are divers floating Islands, most of them Inhabited, in one of them is a Church with a Monastery."

"In the Year 1276 the Countess of Heneberg Daughter to Florent the 4th Earl of Holland, had at one Birth 365 Children, all baptized by Don William suffragan Bishop of Treves, in two Brazen Dishes, in the Village of Lofdeen."

Who can refuse credence to a fact so circumstantially set forth?

Taylor's Almanac for 1720 was issued by the same "Andrew Bradford at the sign of the Bible in Second Street."

At the head each of the twelve pages of the almanac on which the calculations for the months are set forth is a piece of poetry, and toward the end of the volume occurs a remarkable piece of rhyme, entitled A Cronology, setting forth various odd occurrences.

In Taylor's Almanac for 1723 we find the following poem :

"Full Forty years have now their changes made,
Since the foundation of this town was laid.
When Jove and Saturn were in Leo joined;
They saw the survey of the place design'd;
Swift were those planets, and the world will own
Swift was the progress of the rising town.
The Lion is an active Regal sign,
And Sol beheld the two superiors join,
A city built with such Propitious rays,
Will stand to see old Walls and happy days."

In Taylor's Almanac for 1737 occurs the following ;

Take half an Ounce of Rainbows fil'd to dust,
Three grains of Party-Papers true and just,
One grain of Satyrs, candid, just and fit,
Without Illnature, cant or dev'lsh wit;
Mix these with Art to make the sov'reign Pills,
That cured Train of Epidemic Ills.

In the MSS is written in an old hand on the page for December, "The 7th near 11 at night a shock of an earthquake generally felt through the Province but no damage as I've heard of."

In Taylor's Almanac for 1738 occurs the following poetical description of the Province of Pennsylvania :

"In this new world, so lately here begun,
A thousand miles our King's dominions run;
About the centre lies well known to fame
The Silvan shade that bears the Land Lord's name.
A fruitful soil with gifts of nature blest,
Improved by culture swifter than the rest.
Like Palestine a land of good repute,
For wheat and barley, honey, milk and fruit.
Here not in vain the Master's skilful hand
Manures the glebe, and cultivates the land:
The ground producing ev'ry sort of grain,
Pomarious profit, and the hortensian gain.
Except not Rice, some by experience know,
That useful grain will here in plenty grow.
In wool and flax the Province will be made
Too rich in time to call for foreign aid.
And useful Hemp, its service to declare.
Four Clerks would fail, Accountants all despair.
Its magic-virtue in a skilful hand,
Preserves the substance of a prudent land;
Who can at large its various uses tell?
What Clouds of Canvass on the Ocean swell!
Th' extensive use of Cordage to declare,
The Labour might with *Pliny's* works compare.
I only touch the profits of the field;
And leave the Task for stronger hands to wield.
And now my wild unbounded fancy roves
In that vast region of the trees and groves;
But, lest therein, I scarce pretend to know
What sorts of Oak in this great forest grow;
As many kinds, some say, as metals ly
Beneath the ground, or Planets in the sky,

The chestnut tree for various uses good,
Though soft and tender yet a lasting wood;
Where numerous Chestnuts shade the fertile ground,
Good fence with ease may spacious fields surround.
As for the nuts, they may with acorns join,
A noble mast for saginating swine.
The cedar, spruce and cypress here are seen,
The pine and laurel, these are very green,
The ash, the beech, the maple chiefly grow
By streams of waters and in vallies low.
The sable walnut, and the locust strong
Grow here in groves, and wrestle in the throng.
The poplar's lofty head the clouds invades,
The spreading boughs defusing lovely shades.
The fir-tree may the lofty mountain grace
And pines in gardens man for beauty place;
But, while the verdure leaves, in none you see,
A nobler prospect than the popler tree.
Here liquid Sugar drops from wounded trees,
And aspen groves invite the gentle breeze.
And now behold the lofty hills arise,
That bear the arches of th' impending skies,
Observe the rivals, and decide between
Celestial azure and the mountan green.
Behold the groves, consider well the skie,
And say wherein the greater beauties ly.
Which most the Mind with joy and wonder fills,
The sky-blue curtain, or the verdant hills.
When Israel's sons were led by Moses' hand,
Who told the glories of the holy land,
Melodious Themes the sacred Leader sings,
Of hills and vallies, fountains, brooks and springs.
What grov'ling Soul with patience can sustain
The dull flat prospect of a constant plain;
And ne'er reflect what precious treasure fills
These *ancient mountains and the lasting hills.* Deut. 33. 15
No dreams of gold or views of argent veins
T' involve the land in war, the poor in chains.
I sing the treasure now before your Eyes,
The growing profit and the solid prize.
The well-know metal of a gen'ral use,
In copious stores the bounteous hills produce;
The neighboring groves, the trees, as plenty grow,
To melt the ore and make the metal flow.
The world's last age may terminate the store
Of trees above, and under ground the oar.
To know what profit may from thence be made
Ask not the stars, nor seek a Python's aid;
As when you see the rising Tyde begin,
And from the Ocean flouds come rolling in,
It moves no wonder, gives you no surprise,
The swelling water will by nature rise.
So when a hundred kilns and forges glow,
A thousand streams of melted metal flow,
Not the possessors of the Mines alone
Will hoard the gain and make it all their own.
The trade and profit, circling like the blood,
Will then become a universal good.

This most peculiar blessing rarely fails,
The happy land adorned with hills and vales,
The crystal springs that wash the mountain's side,
Start from the hills and through the valleys glide,
Collect their force from single drops begun,
Unite their streams, enlarging as they run;
From brook to brook discharge the liquid store,
Till ample Rivers in procession roar.
Where these abound who can the blessing tell
Which all enjoy and few consider well.
Upon the horrid fields of driving sand,
Betwixt *Numedia* and the Negro's land,
A merchant's tomb his monument remains
Who dy'd of thirst upon the scorching plain:
A greedy carrier, fond of sacred gold,
A draught of water to the merchant sold,
Ten thousand Ducats was the price it cost,
So dear he paid his dearer life he lost.
Who can behold the springs and purling rills
In sweet Meanders gliding down the hills,
And not remember these unhappy plains,
Where horror dwells and death forever reigns?

In June is written in an old hand "y^e^ Governour arrived y^e^ 1^st^ day."

In August of this year;

If needless, things we laid aside,
A woman destitute of Pride,
Bohea *and* Green *would scarcely steer*
Twelve thousand miles to find us here.

Taylor for 1741 is filled with quotations from Paradise Lost.

Taylor's Almanac for 1743 was "printed and sold by ISAIAH WARNER almost opposite to CHARLES BROCKDEN'S, in *Chesnut-Street;*" and contains

"The *Indian Prophecy.*

"An Indian of this Province looking at the great Comet *Anno* 1680, being asked what he thought was the Meaning of that prodigious Appearance, his answer was, "*It signifies that we Indians shall melt away and this country be inhabited by another sort of People.*" This Prediction the *Indian* delivered very grave and positive, to a *Dutchman* of good Reputation, living there and many Years since near *Chester*, on *Delaware*, who related the same punctually to an *Englishman*, now living, whose Veracity, I think, is never questioned." The chain of evidence here is certainly very remarkable, but cannot be called conclusive. In the same Almanac at the end of an article on Politics occurs these words: "from us to the river *St. Laurence*, we know the space too well. I could wish that his most Christian Majesty had, in lieu of that, a Country ten times better, and a thousand times the distance."

Taylor's Almanac for 1744, was "Printed and sold by I. WARNER and C. BRADFORD at the sign of the BIBLE in *Front-Street.*"

The whole collection, filled with quaint and curious matter of which the foregoing is a fair specimen, is well worthy of attention as an example of early printing in Pennsylvania. The orthography is extremely unsettled, and the grammar equally uncertain.

Stated Meeting, March 4, 1881.

Present, 13 members.

President, Mr. FRALEY, in the Chair.

Mr. Ames and Dr. Wurtz, new members, were introduced to the presiding officer and took their seats.

A letter acknowledging receipt of Diploma was received from Prof. James Geikie, dated Perth, Scotland, July 14, 1881.

The thanks of the American Institute of Mining Engineers for the use of the Hall was received.

The request for correspondence of the Vermont Historical Society was read and agreed to.

Letters of envoy and acknowledgment were read.

Donations for the Library were received from the Academies at St. Petersburgh, Berlin, Vienna, Rome and Dublin; the Societies at Königsburg Dresden, Halle and Giessen; the Geological Society at Berlin; the Geological International Commission, Lausanne; the Würtemberg Land History Society at Stutgart; the Zoologischer Anzeiger; the Zoölogical Garden at Frankford; the Revista Euskara at Pamplona; the the Bureau of Statistics at Brussels; the Paris Geographical Society, Polytechnic School and Political Review; the Geographical Commercial Society at Bordeaux; the Institute for Earth Magnetism at Vienna; the Royal Society, London; the Greenwich Observatory, the Adelaide Observatory, the Meteorological Society, the Royal Geographical Society, the Geological Society, the Linnean Society, the Zoölogical Society, the Royal Asiatic Society and the Society of Arts, London; the Radcliff Observatory at Oxford; R. Cornwall Polytechnic Society; the Philosophical and Literary Society, Leeds; and Mr. James Henry of Dublin.

Mr. Lesley read a paper entitled "Notes on the meaning of the word *Hebrews*, and on Egyptian names of Hebrew kings."

Pending nominations Nos. 927 to 931, and new nomination No. 932 were read.

And the meeting was adjourned.

Stated Meeting, March 18, 1881.

Present, 13 members.

President, Mr. FRALEY, in the Chair.

The resignation of Dr. C. J. Stillé, dated February 17, 1881, was received and accepted.

A letter of thanks for the gift of a copy in oil of the portrait of Michaux, was received from the Commissioners of the Fairmount Park, dated March 12, 1881.

A letter requesting the deposit of historical documents in the hall of the Historical Society of Pennsylvania was referred to the Library Committee, the Librarian and Dr. Horn, to report.

Letters of acknowledgment were received from the London Statistical Society (106 and List); the Society of Antiquaries (106); New Bedford Library (107); and the Cincinnati Observatory (107).

Letters of envoy were received from the Geological Survey of India, July, 1880; the Austrian Academy, Aug. 25; Prof. W. F. Hewitt, Ithaca, March 16; and the U. S. Coast and Geodetic Survey, March 15, 1881.

Donations for the Library were received from the Geological Survey of India; the Academies at Turin, Rome, Modena, Copenhagen and Brussels; the Turin Observatory; the Institutes at Milan and Venice; Prof. Gio. Capellini, Bologna; the Geological Commission at Florence; the Geographical Societies at Paris and Bordeaux; the Flora Batava; the British Topographical Society; London Nature; the American Statistical Association; Mr. Samuel Scudder; Museum C. Z. Cambridge; New Bedford Library; Dr. Geo. W. Hawes; American Journal A. and S.; New York Academy of Sciences, State Museum, and Prof. Jas. Hall; Prof. W. T. Hewett, Ithaca; Buffalo Nat. Hist. Society; Trenton Experimental Station; Franklin Institute, Num. and Antiq. Society, Journal of Pharmacy, Medical News, Mr. Reuben Haines and Mr. H. Phillips, Jr., Philadel-

phia; Gov. Hoyt; U. S. N. Observatory; U. S. C. and G. Survey; Mr. Jed. Hotchkiss, Staunton, Va.; San Franc. Mer. Association; Min. de Fom. and M. M. Barcena, Mexico.

The death of Dr. John J. Bigsby was announced by the Secretary, with remarks on his early connection with geological exploration in America.

The death of Prof. John Johnston, at Middlebury, Connecticut, in 1879, was reported.

A memoir On the Preglacial drainage of Lake Erie and the other great lakes, by Dr. J. W. Spencer, was read and illustrated by the Secretary.

A paper on "A Geological Section at St. Mary's, in Elk County, Pa.," was read by Mr. Ashburner.

Pending nominations, Nos. 927 to 932, and new nomination, No. 933, were read.

And the meeting was adjourned.

Discovery of the Preglacial Outlet of the Basin of Lake Erie into that of Lake Ontario; with Notes on the Origin of our Lower Great Lakes. By J. W. Spencer, B. A. Sc., Ph.D., F.G.S., King's College, Windsor, N. S.

(*Read before the American Philosophical Society, March* 18, 1881.)

SUMMARY.

The object of this paper is to bring before the scientific world the following observations, bearing on the Preglacial Drainage and origin of our Great Lake Basins:

1. The Niagara escarpment, after skirting the southern shores of Lake Ontario, bends at nearly right angles in the neighborhood of Hamilton, at the western end of the lake; thence the trend is northward to Lake Huron. At the extreme western end of the lake this escarpment (at a height of about 500 feet) encloses a valley gradually narrowing to four miles, at the meridian of the western part of the city of Hamilton, where it suddenly closes to a width of a little more than two miles, to form the eastern end of the Dundas valley (proper). This valley has its two sides nearly parallel, and is bounded by vertical escarpments, which are capped with a great thickness of Niagara limestone, but having the lower beds of the slopes composed of Medina shales. On its northern side the escarpment extends for six miles to Copetown; but westward of this village it is covered with

drift, but it is not absent. On its southern side the steep slopes extend for less than four miles to Ancaster, where they abruptly end in a great deposit of drift, which there fills the valley to near its summit, but which is partly re-excavated by the modern streams, forming gorges from two to three hundred feet deep. To the north-eastward of Ancaster these gorges are cut down through the drift to nearly the present lake level.

Westward of Ancaster, a basin occupying a hundred square miles, where the drift is found to a great depth, forms the western extension of the Dundas valley. With the north-western and western portions of this drift-filled area the upper portion of the Grand river and Neith's creek were formerly connected. The Grand river, from Brantford to Seneca, runs near the southern boundary of this basin, then it enters its old valley, which extends from Seneca to Cayuga, with a breadth of two miles, and a depth, in modern times, of seventy-five feet, having its bed but a few feet above the surface of Lake Erie. Near Cayuga, the deepest portion of the river-bed is below the level of Lake Erie.

2. The Dundas valley and the country westward form a portion of a great *river valley*, filled with drift. Along and near its present southern margin this drift has been penetrated to 227 feet below the surface of Lake Ontario, thus producing a *cañon* with a lateral depth of 743 feet, but with a computed depth, in the middle of its course, of about 1000 feet.

3. The Grand river, at four miles south of Galt, has, since the Ice Age, left its ancient bed, which formerly connected with that of the Dundas valley, as did also Neith's creek, at Paris.

4. Lake Erie emptied by a buried channel a few miles westward of the present mouth of the Grand river, and flowed for half a dozen miles to near Cayuga, where it entered the present valley, and continued this channel (reversed) to a place at a short distance westward of Seneca, whence it turned into the basin referred to above, receiving the upper waters of the Grand river and Neith's creek as tributaries, and then emptied into Lake Ontario by the Dundas valley. This channel was also deep enough to drain Lake Huron.

5. Throughout nearly the whole length of Lake Ontario, and at no great distance from its southern shore, there is a submerged escarpment (of the Hudson River Formation) which, in magnitude, is comparable with the Niagara escarpment itself, now skirting the lake shore. It was along the foot of this escarpment that the river from the Dundas valley flowed (giving it the present form) to eastward of or near to Oswego, receiving many streams along its course.

5. The western portion of the Lake Erie basin, the south-western counties of Ontario, and the southern portion of the basin of Lake Huron formed one Preglacial plane, which is now covered with drift or water (or with both) to a depth varying from fifty to one hundred feet, excepting in channels where the filling by drift is very great. A deep channel draining Lake Huron extended through this region, leaving the present lake near the Au Sable river, and entering the Erie basin between Port Stanley and

Vienna, at a depth near its known margin of 200 feet, but at a probable depth in the centre sufficiently great to drain Lake Huron.

6. The Preglacial valleys (now buried) of Ohio and Pennsylvania—for example; the Cuyahoga, Mahoning (reversed), and Allegheny (deflected), formed tributaries to the great river flowing through the Erie basin and the Dundas valley.

7. The bays and inlets north of Lake Huron are true fiords in character, and are of aqueous origin.

8. The Great Lakes owe their existence to sub-aërial and fluviatile agencies, being old valleys of erosion of great age, but with their outlets closed by drift. Glaciers did not excavate the lakes and had no important action in bringing about the present topography of the basins.

9. The old outlet of the Niagara river, by the valley of St. David's, was probably an interglacial channel.

I. Introduction.

Whilst residing in Hamilton, Ontario (1877–80), a portion of my time was devoted to studying the geology of the neighborhood. At first it began in connection with Lieut. Col. Grant, H. P., Sixteenth Regiment, and some other gentlemen, in making collections of fossils; as this locality is one of the best for obtaining Niagara Fossils (and also those of the Hudson River Formation from the drift pebbles in the beaches) in Canada. In 1874, the present writer published in the *Canadian Naturalist* a sketch of the local geology. In 1878, he laid the plan of collecting the information necessary for preparing an exhaustive paper on the Geology of the region about the Western End of Lake Ontario. When systematic work was commenced, the information gained required so much time for its study that it has long delayed the publication. A large number of new species of Niagara fossils (twenty-nine of the Graptolite family alone) were obtained. The present state of the work is, that a paper on the Palæozoic Geology, and another on the Palæontology, containing descriptions of many new fossil species, are ready for publication. A third portion, on the Surface Geology, is under way; and the investigations on this subject have, step by step, carried the writer outside of his original field,—having assumed an importance never anticipated; and have resulted in this advance notice of a few of the most striking facts concerning the origin of our great lakes. The completion of the work will be further delayed until opportunity will have been afforded to study some questionable points, especially such as relate to the drift deposits of the region, and others having a broader bearing on the physical geography of the lake regions in Preglacial times.

In the present paper, all discussion relating to the vexed glacial hypothesis is scrupulously avoided, except those questions bearing on a true explanation of the origin of our great lakes.

In the study of the surface geology, the first great question that presented itself was, "What is the origin of my native valley, Dundas?" The

possibility of Lake Erie flowing down through the Dundas valley (though it suggested itself) did not seem probable, owing to the high lands between the two great lakes. However, in the *Canadian Naturalist*, 1874, I referred to it as having been produced by a "mighty river." This was like one of those gratuitous hypotheses that are common, now-a-days, for attributing to a continental ice sheet most of the causes of the present physical features of the continent, which do not readily explain themselves. Subsequently, Mr. George J. Hinde refers to it as having been scooped out by a glacier. This assertion will be found in the sequel to be a perfectly untenable hypothesis. Certainly, the origin of the valley was obscure, yet it showed that the excavation of a *cañon* of such magnitude required a proportionately great agent; and no present stream would account for even a small portion of the excavation. However, in this paper it will be seen that its existence was unquestionably occasioned by the action of a mighty river, as originally suggested. This outlet of Lake Erie also perfectly accords with, and accounts for the preglacial drainage of Pennsylvania, as made known at the close of last year by Mr. Carll, of the Geological Survey of that State.

II. Topography of the Region about the Western End of Lake Ontario.

The Niagara Escarpment.—This range of hills commences its course in Central New York, and extends westward, at no great distance south of Lake Ontario. It enters Canada at Queenston Heights, and thence its trend is to the western end of the lake, where, near Hamilton, it turns northward and extends to Cabot's head and Maintoulin island. Everywhere in Canada, south of Lake Ontario, it has an abrupt fall looking towards the northward; but at Thorold and other places to the eastward its bow is more broken than at Grimsby, and westward. At Hamilton, the brow of the escarpment varies from 388 to 396 feet above Lake Ontario.* About five miles east of Hamilton, the escarpment makes an abrupt bend enclosing a triangular valley, down which Rosseaux creek, and other streams now flow. This valley is about two miles wide at its mouth, and has a length of about the same distance.

About five miles westward of Hamilton, the Niagara escarpment becomes covered with the drift deposits of a broken country, or rather ends abruptly in the drift of the region. Above the range, the country gradually rises to the divide between Lake Ontario and the Grand river, or Lake Erie, without any conspicuous features. South-eastward of Hamilton, at a point about five miles from the brow of the escarpment, where the Ham-

* Prof. Dana places the mean level of Lake Ontario at 233.5 feet above ocean-level; the Canadian Geological Survey, at 232 feet; the New York Central Railroad, at 249.84; the Geological Survey of Pennsylvania, takes 573 feet as the mean of the results of determining the level of Lake Erie; the Welland canal levels show Lake Erie as being 326.75 feet higher than Lake Ontario; and the Hamilton and North Western Railway a difference of 328 feet, both of these last routes being short lines with direct courses. Therefore the height of Lake Ontario should be about 245 feet above the sea.

ilton and North Western Railway reaches the summit, the altitude above Lake Ontario is 493 feet. At Carpenter's quarry, two miles southward of the "mountain" brow, at the head of James street, the altitude reaches 485 feet; and near Ancaster the summit is 510 feet above Lake Ontario. From eastward of Grimsby (for twenty miles) to near Ancaster, the escarpment presents an abrupt face from 150 to 250 feet below the summit (having a moderate amount of *talus* at the base), thence it extends by a more or less steep series of slopes to the plane, which gradually inclines (sometimes by a succession of terraces), to the lake margin.

On the northern side of the town of Dundas, the abrupt face of the escarpment looks southward, and extends four or five miles westward, until the exposure becomes covered by the drift deposits near Copetown station, similar to the termination at Ancaster on the south side of the Dundas valley, but not by an abrupt ending as at the latter locality. About two miles east of the G. W. Railway station, at Dundas, the trend of the range bends more to the northward, and from this point there is a marked difference in the configuration of the country below the summit. The range, after extending beyond Waterdown, turns still more to the northward and passes near Milton, and Limehouse station (on the G. T. Railway), and thence extends to Georgian bay. The height of Copetown above the lake is 502 feet. On the west side of Glen Spencer it is 409 feet, and eastward of the same gorge the highest point is 520 feet (Niagara limestone coming within four feet of the surface). At Waterdown the altitude is over 500 feet (?) and at Limehouse the brow of the range (though only the lower beds of the Niagara limestones occur) is 810 feet. The features of the surface of the country above the highlands north of Dundas are much more varied than south of the Dundas valley. As the trend of the escarpment turns northward around the end of the lake, the face of the slope looks towards the eastward. But the country does not present the steep declivities as exhibited along the southern side of Lake Ontario; for the vertical face is usually less than 100 feet, and the country between it and the water has a more uniform pitch.

Basin of Lake Ontario. As is well known, Lake Ontario consists of a broad, shallow (considering its size) basin, excavated on the southern margin out of the Medina shales, and having its southern shores from one to several miles from the foot of the Niagara escarpment. The Medina shales form the western margin (where not covered with drift) to a point near Oakville. From this town to a point some distance eastward of Toronto, the hard rocks are made up of the different beds of Hudson River Epoch; while the soft Utica shales occupies the middle portion, and the Trenton limestones the portion of the Province towards the eastern end of the lake.

The country at the western end of the lake consists of slopes gently rising to the foot of the Niagara escarpment, noticed before. Sometimes this elevation is by terraces, and again by inclines so gentle, as between the foot of the escarpment at Limehouse (on the G. T. Railway) and the lake, where

the difference of altitude above the water is more than 700 feet, without any very conspicuous features.

At the western end of the lake, the two shores converge at an acute angle. At about five miles from the apex of this angle is the low Burlington beach, thrown across the waters in a slightly curved line, which forms the western end of the open lake. Burlington lake, thus formed, is connected with the open lake by a canal of the same name, made where there was a former shallow opening between the waters within and without the beach. This beach is made up of sand and pebbles (mostly of Hudson River Age), and is more than four miles long, but nowhere is it half a mile wide.

No mean depth of Lake Ontario can be fairly stated. For geological purposes it has no mean depth, because it is simply a long channel with the adjacent low lands covered by back-water.

West of the meridian of the Niagara river the lake is evidently filled with more silt then eastward, as we find that the bottom slopes more gradually towards the centre, where the mean depth (increasing from the westward) of the channel may be fairly placed at 400 feet below the present surface of the waters. In this section of the lake, the average slope from both shores may be stated at 30 feet in a mile. At a short distance east of the 78th meridian, the character of the late bottom changes in a most conspicuous manner. Here we find a deeper channel which extends for more than ninety miles, having an average depth of about 90 fathoms or 540 feet, with, in some places, a trough of about 600 feet depth, generally near the southern margin of the 90-fathom channel. Here and there is a deeper sounding—the deepest being 123 fathoms or 738 feet. The long channel, surrounded by the 90-fathom contour line, is situated at a mean distance of not less than twenty miles from the Canadian shore, whilst its southern side approaches in some places to within six miles of the American shore, with which it is parallel. This 90-fathom channel varies from three to twelve miles in width. Its broadest and deepest portion is south of the Canadian peninsula of Prince Edwards' County.

The mean slope of the lake bottom, from the Canadian shore to this deep channel just pointed out, may be placed at less than twenty-five feet in a mile, with variations from twenty to thirty feet in that distance. The mean slope from the New York shore line to the 90-fathom channel may be placed at sixty feet in a mile, but varying generally from fifty to ninety feet. On examination we find that the greater portion of this slope belongs to a belt which descends much more rapidly than the off-shore depression.

That the southern side of Lake Ontario has a submerged series of escarpments or one moderately steep and of great dimensions, is manifest when we come to study the soundings. In fact, if the bed of Lake Ontario were lifted out of the water, this submerged escarpment would be more conspicuous than the greater portion of the present one, known by the name of the Niagara. In many places the descent from the table-land above the Niagara escarpment is no more precipitous than the slopes of the sub-

merged Cambro-Silurian (Hudson River, in part, if not throughout the entire length) rocks, with its sloping summit, in part crowned by a gently sloping surface of Medina shales. Nearly north of the mouth of the Genesee river we find that within a single mile the soundings vary from forty-three to seventy-eight fathoms (between contour lines). This gives a sudden descent in one mile of 210 feet. As the soundings are not taken continuously to show to the contrary, most of the change of levels may be within a few hundred yards.

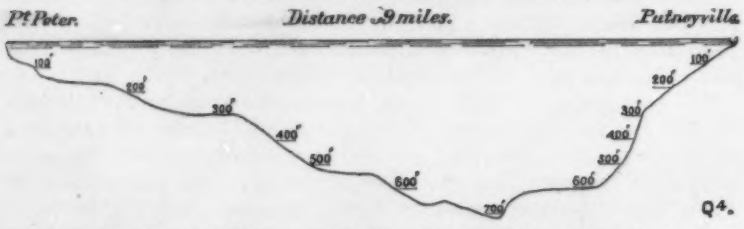
In the region of these soundings the deepest water outside of the 78-fathom line is 84 fathoms, while from the shore to the 43-fathom sounding the least distance is four and a half miles, thus giving the greatest mean slope of the lake bottom at sixty feet in a mile, before the escarpment is reached.

An excellent series of soundings can be studied in a line nearly northward from Pultneyville, N. Y.:

Distance from Pultneyville	Depth of Sounding.	Slope from previous Sounding.
0.5 miles.	42 feet.	
1.0 "	72 "	60 feet per mile.
1.75 "	126 "	72 " "
4.125 "	246 "	50 " "
5.0 " } Face of the	{ 372 " }	144 " "
6.0 " } escarpment.	{ 582 " }	210 " "
7.0 "	624 "	42 " "
10.0 "	642 "	6 " "
12.0 "	738 "	48 " "

Fig. 1.

Section of Lake Ontario from Point Peter Light, Ontario, to Putneyville, N.Y.

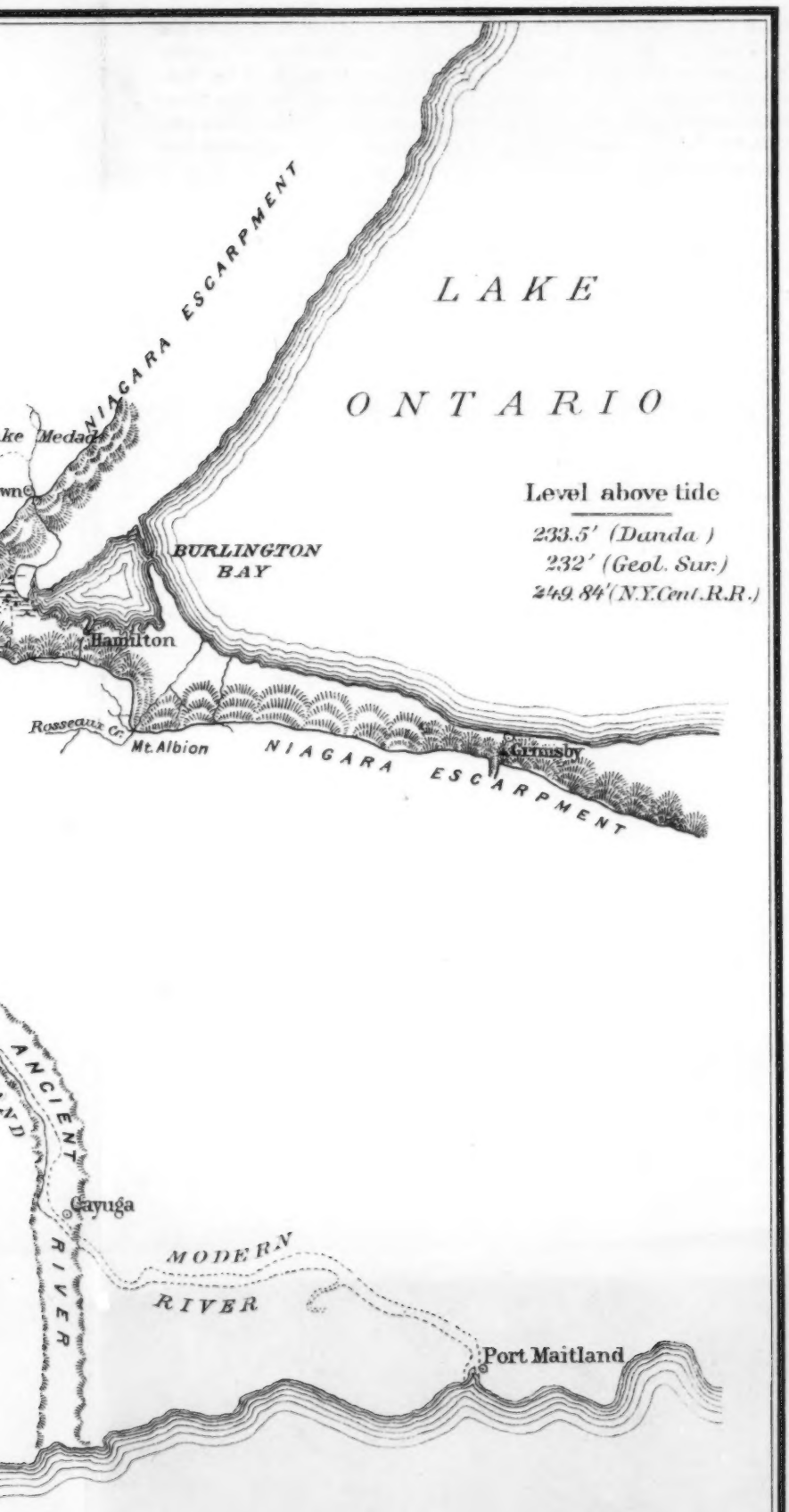


From this table it will be seen that in a distance of less than two miles the slope of the escarpment is the difference between 582 and 246 feet, or 336 feet as actually recorded. At Hamilton, the Niagara escarpment is only 388 feet above the lake, which is two miles distant, whilst the present slope at Thorold is spread over nearly twice that distance. That this escarpment is not local is easily seen. For a distance of over forty miles, from near Oswego westward, it plunges down 300 feet or more in a breadth varying from less than two to three miles. Eastward and westward of this portion of the lake this submerged escarpment can be traced for nearly

Guelph
Grand River
River Speed
Galt
River Nith or Canning
Lindsay Creek
Lake Medad
Waterdown
Webster Falls
Spencer Falls 316'
Troy
Fairchild Creek
Capetown
240'
360'
Ancaster 510
Hamilton
480'
Paris 496
100'+
Jerseyville 485'
403'
Rosseaux Cr.
Mt. Albion
Brantford
CANON OF ANCIENT GRAND RIVER
Seneca
Cayuga
Tilsonburg
Otter Creek
Big Creek
Vienna
LAKE ERIE
LONG POINT
Level of Lake Erie 573 above tide.

LANE S. HART STATE PRINTER

Guelph
River Speed
Galt
Lindsay Creek
Lake Medad
Waterdown
Webster Falls
Spencer Falls
516'
Troy
Capetown
Fairchild's Creek
480'
240'
360'
Ancaster
510
Rosseau
Jerseyville
465'
405'
100+
Brantford
CANON OF ANCIENT GRAND RIVER
Seneca
Gayu
LAKE E
LONG POINT



SECOND GEOLOGICAL SURVEY
OF PENNSYLVANIA
J.P. LESLEY, State Geologist.

PREGLACIAL DRAINAGE
INTO THE
WESTERN END OF LAKE ONTARIO

by

Dr. J.W. Spencer, F.G.S.

Scale

0 5 10

REFERENCES

Preglacial Rivers _____

Modern Rivers differing from Preglacial - - - - - -

Margin of Basin with limestone floor absent — — — —

JULIUS BIEN, PHOTO. LITH.

one hundred miles, but with the portion deeper than the 70-fathom contour having more gradual soundings, as the base of the hills either originally had a more gradual slope, or the lake in its western extension has subsequently been filled with more silt.

Although we have not soundings made very close together, yet the admirable work of the United States Lake Survey is more than sufficient to prove the existing of a continuous escarpment that has an important bearing on the Preglacial geography of the region, and on the explanation of the origin of the Great Lakes themselves.

The soundings do not show a conspicuous escarpment after passing westward of the meridian of Niagara river, partly on account of the sediments filling this portion of the lake, and partly because the lake in all probability never had its channel excavated to so great a depth as farther eastward.

Attention must be called to the fact that the depth of the Niagara river is 12 fathoms near its mouth, but that the lake around the outlet of the river has not a depth exceeding four fathoms with a rocky bottom.

Another escarpment at the level of Lake Ontario, now buried, was discovered by the engineers of the enlargement of the Welland canal, according to Prof. Claypole (Can. Nat. Vol. ix, No. 4). When constructing, No. 1 lock, at Port Dalhousie, it was found that at its northern end, there was an absence of hard rock which formed the foundation of its southern end. Rods more than 40 feet long were pushed into the slimy earth without meeting any hard rock bottom. This discovery will be noticed in the sequel. *

Basin of Lake Erie. The exceedingly shallow basin of Lake Erie has its bottom as near a level plane as any terrestrial tract could be. Its mean depth, or even maxima and minima depths from its western end for more than 150 miles, scarcely varies from 12 or 13 fathoms for the greater portion of its width. The eastern 20 miles has also a bed no deeper than the western portion. Between these two portions of the lake, the hydrography shows an area with twice this depth (the deepest sounding being 35 fathoms). This deepest portion skirts Long Point (the extremity, a modern peninsula of lacustrine origin), and has a somewhat transverse course. An area of less than 40 miles long has a depth of more than 20 fathoms. The deeper channel seems to turn around Long Point, and take a course towards Haldemand county, in our Canadian Province, somewhere west of Maitland. The outlet of the lake, in the direction of the Niagara river, has a rocky bottom (Coniferous limestone).

The study of this lake at first appears less practicable than that of Ontario, but, when its former outlet and its tributary rivers are described, the writer trusts that he will have made some observations, that may help to clear the darkness that hangs about the history of our interesting lake region, before the advent of the Ice Age.

The Dundas Valley and adjacent Cañons. We may consider that the

* See Report of Chief Engineer of Canadian Canals, 1880.

Dundas valley begins at the "bluff" east of the Hamilton reservoir, and extends westward, including the location of the city of Hamilton and the Burlington bay, at least its western portion. With this definition, the width at the Burlington heights (an old lake terrace 108 feet above present level of the water) would be less than five miles. At a mile and half westward of the heights, the valley suddenly becomes narrowed (equally on both sides of its axis of direction, by the Niagara escarpment making two equal concave bends, on each side of the valley, whence the straight upper portion extends, the whole resembling the outline of a thistle and its stem), from which place it extends six miles westward to Copetown, on the northern side; and three and a half to Ancaster, on its southern side. The breadth between the limestone walls of this valley varies somewhat from two to two and a half miles. The summit angles of the limestone walls on both sides are decidedly sharp.

Dundas town is situated in this valley, its centre having a height of about 70 feet above Lake Ontario, but its sides rise in terraces or abrupt hills; and on ascending the valley, we find that between the escarpments are great ranges of parallel hills separated by deep gorges or glens, excavated in the drift by modern streams. This rugged character continues until the summit of the Post Pliocene ridges have a height equal to that of the escarpment. As the gorges ascend towards the westward, they become smaller, until at some distance south-west of Copetown and Ancaster, the divide of the present system of drainage is reached. Some of these streams have cut through the drift, so that they have only an altitude above the lake (which is seven miles distant) of 240 feet, while the tops of the ridges immediately in the neighborhood are not much less than 400 feet high, though they themselves have been removed to a depth of about another hundred feet, for the drift has filled the upper portion of the valley to the height of 500 feet above Lake Ontario. Even to the very sources of the streams, the country resembles the rivers of our great North Western Territories (or those of the Western States), cutting their way through a deep drift at high altitudes, which is not underlaid by harder rocks, showing deep valleys rapidly increasing in size and depth, as they are cleaning out the soft material, and hurrying down to lower levels—a strong contrast to the features in most other portions of our Province.

On the south side of the Dundas valley, a few unimportant streams, mostly dry in summer, have worn back the limestone escarpment, over which they flow, to distances varying from a few yards to a few hundred, making glens at whose head in spring time some picturesque cascades can be seen. At Mount Albion, six miles east of Hamilton, there are two of these larger gorges, whose waters, after passing over picturesque falls, 70 feet high, and through glens several hundred yards in length, empty into the triangular valley noticed before. On the north side of the Dundas valley, besides small gorges with their streams comparable to those on the south side, there are several of much larger dimensions; for example, that at Waterdown, six miles north of Hamilton. Still larger is Glen Spencer which has a *cañon* half

a mile long, 300 feet deep and between 200 and 300 yards wide at its mouth. At the head of this is Spencer Falls, 135 feet high, and joining it laterally there is another *cañon*, with a considerable stream flowing from Webster's Falls, which, however, is of less height than the other. The waters feeding their streams come from northward of the escarpment, and belong to a system of drainage different from those streams which flow down through the drift of the Dundas valley, and are of much greater length. At the foot of Spencer Falls, the waters strike the upper portion of the Clinton shaly beds. The Falls now are two feet deeper than twenty years ago. Yet the stream is small, and makes a pond below in the soft shales. But this difference in height does not represent the rate of wearing or recession of the precipice. That the stream is much smaller than formerly is plainly to be seen, for at present it has cut a narrow channel, from ten to fifteen yards in width, above the falls, and from four to six feet deep, on one side of the more ancient valley, which is about 50 yards wide and 30 feet deep, excavated in the Niagara dolomites.

The surfaces of the escarpment in both sides of Glens Spencer and Webster present a peculiar aspect. That on the north-eastern side has a maximum height of 520 feet above the lake. On the same side, a section made longitudinally shows several broad shallow glens nearly a hundred feet deep crossing it and entering Glen Spencer. The surface of the rocks is glaciated, but not parallel with the direction of the channels. On the south-western side of the same *cañon*, we find that a portion of the thin beds of Upper Niagara limestone have been removed. This absence is not general, for it soon regains its average height of about 500 feet.

Dundas Marsh. The eastern end of the Dundas valley contains a large swamp, nearly three miles long, with a breadth of about three-fourths of a mile, known in the early settlement of the country by the name of Coote's Paradise.

This marsh was formerly connected by a small rivulet with Burlington bay, but this was subsequently closed by the G. W. Railway, when the cutting of Desjardin's canal through Burlington heights was completed. Into this marsh all the drainage of the Dundas valley is deposited, causing it to fill up at the rate of one-tenth of a foot per annum.

Burlington Heights. Across the eastern end of the Dundas swamp and some of its branches, are the Burlington Heights, varying from a few hundred yards to nearly a quarter of a mile in width, and over 100 feet in height, which have been an old beach, at a time when the lake level was at the same elevation, for we find that a lake beach extends along the flanks of the escarpment, both eastward and northward for a considerable distance at the same level. This is mentioned here as forming a most conspicuous terrace, and as changing the physical character of the western extremity of Burlington bay, and the outlet of the Dundas valley. Various terraces and beaches are found, both at lower levels, and also fragments at higher altitudes, or along the side of the "mountain," until some attain a height of 500 feet above Lake Ontario.

The Grand River Valley. The Grand river of Ontario rises in the County of Gray, not more than twenty-five miles from Georgian bay. Thence it flows southward, and at Elora the river assumes a conspicuous feature. Here it cuts through the Guelph Dolomites to a depth of about 80 feet and forms a *cañon* about 100 feet in width with vertical walls. At this place it is joined by a rivulet from the west, which has formed a tributary *cañon* similar to that of the Grand river itself.

The country in this region is so flat that it appears as a level plane. Farther southward the river winds over a broader bed, and at Galt the present river valley occupies a portion of a broad depression in a country indicating a former and much more extensive valley. In fact, the old river valley existed in Preglacial times, for the present stream has re-excavated only a part of its old bed at Galt, leaving on the flanks of one of its banks (both of which are) composed of Guelph Dolomites, a deposit of Post Tertiary drift, in the form of a bed of large rounded boulders mostly of Laurentian gneisses. The country for four miles south of Galt is of similar character, forming a broad valley, in which the present river flows. At this distance from Galt the river takes a turn to the south-westward; but at the same place, the old valley appears to pass in a nearly direct line with the course of the present bed (before the modern turn is made to the westward). As this portion of the valley now entered, has not to any extent been cleaned out by modern streams, it forms a broad shallow depression in the country extending for a few miles in width. Yet, it is often occupied with hills composed of stratified coarse gravel belonging to that belt, which extends from Owen Sound to the County of Brent, and called by the Canadian Geological Survey "Artemesia gravel."

It is through a portion of this valley that the Fairchild's creek flows. Many streams derive their supplies of water from the Beverly swamps, which also feed the Lindsay creek, that empties over Webster falls and flows down Glen Spencer through the Dundas valley to Lake Ontario.

The G. W. Railway, at four miles south of Galt, enters this valley and continues in it or its branches as far as Harrisburg, though the deeper depression is near St. George (a short distance west of Harrisburg). After leaving what I consider its more ancient bed, south of Galt (unless the country between the present bed and Fairchild's creek was an island), the Grand river flows southward to Paris and Brantford, having a deep, broad valley. At the latter place the valley may fairly be placed at a few miles in width, while further to the eastward the river winds in an old course, which had formerly a width of over four miles (see map). In the region of Brantford the valley is bounded by a somewhat elevated plateau. At Paris, Neith's creek enters the Grand river from the west, and has a valley almost comparable in size with that of the latter at this town. At Paris, the Grand river cuts through the plaster-bearing Onondaga formation. Similar rocks appear at various places along the river, at places where the river has cleaned out a portion of one side of its ancient valley.

At the Great Western Railway crossing, east of Paris, the bed of the

river has an altitude of 495 feet above Lake Ontario, while at Brantford it is 410 feet (this elevation may not be perfectly accurate) above the same datum. From Brantford the river winds through a broad valley, with a general easterly direction, to Seneca, where the immediate bed is about quarter of a mile wide, flowing at the southern side of a valley, more than two miles wide, and 75 feet below its boundaries, which are 440 feet above Lake Ontario (see profile on subsequent page). At Seneca the bed of the present river-course is 365 feet above Lake Ontario, or only 37 feet above Lake Erie. (The H. & N. W. Railway levels give Lake Erie as 328 feet above Lake Ontario, whilst the Report of the Chief Engineer of the Welland Canal states that the difference of level is 326¾ feet. As these two levels agree so nearly, and as the other figures refer to the railway levels, I have followed them here.) Eastward from Seneca the river continues to have its broad valley as far as Cayuga. To near this town the waters of the Welland canal feeder reach, at a height of about 9 (?) feet above Lake Erie.

From Seneca to Cayuga the direction of the valley is nearly south, but at the latter place it abruptly turns nearly to the eastward, and in a short distance it passes to a flatter country and flows over Coniferous limestone. After a sluggish flow, it enters Lake Erie (passing through a marshy country) at Port Maitland, more than fifteen miles in a direct line from Cayuga. It must be remembered that, from Seneca to Cayuga, the valley is broad and conspicuous. At only a short distance south of the river, at Seneca, the summit of the country is occupied by a gravel ridge.*

Returning to the valley of Fairchild's creek, we find the stream principally flowing in the former bed of the Grand river, abandoned a few miles below Galt since the Ice Age. This creek crosses the Great Western Railway at a level of fifteen feet below the crossing of the Grand river, at a few miles to the westward. Again, the Fairchild's creek crosses the Brantford and Harrisburg railway at an altitude of 407 feet above Lake Ontario, or a little below that of the Grand river at Brantford, although it empties into it a few miles east of the city just named.

Fairchild's creek is now of moderate size meandering through the drift for a width of two miles. This drift is in part stratified clay. The Grand

* The General Manager and Chief Engineer of the air line of the G. W. Railway have recently kindly furnished me with a profile of the railway crossing over the Grand river. A similar favor has been kindly conceded by the Chief Engineer of the Canada Southern Railway. From both of these lines of levels (about a mile apart) we find that the hard rock appears in the drift at a few feet below the bed of the river, but at a level below that of the surface of Lake Erie. The stream, at these places, occupies the eastern portion of the valley about two miles from the northern or north-western boundary of the valley, marked by the contour line of 440 feet above Lake Ontario, noticed south of Seneca, but which also occurs westward of Cayuga, near the general bend in course of the river. On both of these profiles, at about half a mile to the westward of the present site of the river, a depression in the drift occurs to a depth but little inferior to that of the present river-bed. This appears to mark the place where the ancient channel leaves what is now the modern direction of the river for a nearly direct line to the Erie basin.

river from Brantford eastward, is generally excavated from the drift deposits, although occasionally one side of the valley shows rocks of Onondaga formation, exposed by the removal of the drift in modern times. It is also desirable to call attention to the fact that in the region of Brantford, much of the Onondaga Formation is shaly and forms the surface country rock, covering a broad belt, whilst from Seneca eastward, the surface of the country is more generally covered with Coniferous limestone.

Country between the Grand River and Dundas Valleys. The watershed between these two present drainage systems is at only a short distance south-west of Copetown, and the distance in a direction from the Fairchild's to the Dundas side of this divide is less than seven miles, with an average altitude of less than 480 feet (the same as that of the Fairchild's creek as it crosses the Great Western Railway). The highest point that I have leveled is 492 feet above Lake Ontario. On receding westward from the divide, the country gradually descends to the Fairchild's creek, which, as it crosses the Brantford and Harrisburg Railway, is 407 above the lake. It is considerably lower where it enters the Grand river. The region between the divide and the Grand river is traversed from north-west to south-east by a considerable number of streams, all with relatively large valleys, cut in the drift, since the present system of drainage was inaugurated in Post Glacial times.

The country from Jerseyville (about 465 feet above lake) slopes gradually to the Grand river, from six to eight miles distant to the southward.

On examination, it may be seen that the country is too high to permit the Fairchild's creek or Grand river, as they are at present situated, to flow over the height of land into the upper portion of the Dundas valley. As referred to before, the Niagara limestone forming the summit of the escarpment at Ancaster and eastward has a height of about 500 feet. These beds dip at only about 25 feet in a mile (to about 20 degrees west of south) and are not generally covered by a great thickness of drift, but in many places are exposed on or near the surface. Westward of Ancaster these limestones are nowhere to be found, but the country is only covered with drift. At a short distance west of this village, we find streams flowing north-easterly and easterly with very deep valleys in the drift, indicating the absence of the floor of limestone to a depth of over 250 feet below the surface of the escarpment. But on going westward we find that the streams have not cut to an equal depth, but still running deeply through drift. Eventually we reach the divide, after which we find that other systems of streams also cut deeply in the drift running in a south-easterly direction to join the Grand river; but the Niagara limestone is absent from a considerable extent of country.

On the northern side of the Dundas valley the escarpment after reaching Copetown is buried by the drift. Although the line of buried cliffs recedes somewhat to the northward of the Great Western Railway, yet there are occasional exposures, as at Troy and other places in Beverly and Flamboro, where the underlying limestones come to the surface. At

Harrisburg the limestones are known to be absent for a depth of more than 72 feet, as shown in a deep well in the drift.

In the town of Paris one well came upon hard rock at 10 feet below the surface, whilst another at 100 feet in depth, reached no further than boulder clay. This last well must have been in a buried channel of Neith's creek, as outcrops of gypsum-bearing beds of the Onondaga Formation frequently occur near the summit of the hills. From what has just been written, it is easily seen that the Niagara limestones are absent from a more or less horizontal floor (which is over 500 feet above the lake, on both the northern and southern sides of the Dundas valley) which continues from Dundas westward to near Harrisburg, where it meets a portion of the Grand River valley. But almost immediately west of Ancaster we find streams running northward at right angles to the escarpment, and cutting through drift to the depth of almost hundreds of feet. In fact, if we draw a line from Dundas to northward of Harrisburg (a mile or two), and another from Ancaster southward to the Grand river, we have two limits of a region where the limestone floor has been cut away from an otherwise generally level region. The southern side of this area is the southern margin of the Grand River valley, between Seneca and Brantford, and the western boundary is composed of Onondaga rocks east of Paris (which perhaps forms an island of rocks buried more or less in drift).

Additional proofs may be cited. About a mile south of Copetown a well was sunk to the depth of 100 feet before water was obtained. At two miles south east of the same village there is small pond only 240 feet above Lake Ontario, or more than 260 feet below the neighboring escarpment. This is in drift. Again, at a mile north of Jerseyville, the country has a height of 465 feet, with a well in the surface soil to a depth of 40 feet. A small rivulet flows in a valley a few hundred yards south of the last named well which has a bed 435 feet above the lake. At about a mile west of Jerseyville, the altitude is 468 feet with a well 52 feet deep. Again, at about two miles west of the same village, near the county line, the altitude is 460 feet, with a well 57 feet deep (the bottom being lower than the Fairchild's creek more than three miles to the westward). About a mile north of the last named station is a ravine 436 feet with the adjacent hills forty feet higher, and rising in a mile or two to about 500 feet. All these wells are in the drift. From exposures near Ancaster, it appears that the unstratified drift has not an altitude of much more than 400 feet. And as we know that some of these superficial beds are stratified clay, and over most of the country just described not a boulder is to be seen, neither on the surface nor in the material taken from the greater portions of the wells, it is probable that the water is only obtained on reaching the more porous boulder clay below. It has also been noticed that two wells, at least, are 100 feet deep before reaching water, therefore we may fairly place this as about the inferior limit of stratified superficial clays. By reference to the accompanying map, it will be seen that westward of the meridian of Ancaster there is an area of over 100 square miles, where the Niagara floor is

known to be removed everywhere to a depth of 100 feet, and in its eastern portion to more than 260 feet, and still nearer Lake Ontario to a measured depth of more than 200 feet below its waters.

III. Topography and Hydrography of Lakes Superior, Michigan, Huron and St. Clair.

As the origin of all our great lakes is so closely related, it will not be out of place to describe briefly some of the features of the upper lakes that appear most striking. In the present paper it is only intended to call attention to some of the existing physical features of these great basins of water that appear to show a relation which existed in a more or less common origin of all our lakes. Though I have frequently visited many localities on these lakes, for this portion of the present paper I am particularly indebted to General Comstock, Superintendent of the U. S. Lake Survey, who kindly furnished me with the lake charts.

Lake Superior. This lake may be described as a large basin with a level or gently undulating bottom and steep margins. The mean depth may be placed at 800 feet below its present surface. Very few soundings exceed 900 feet. Of these, one near the centre of the basin is 954 feet, and another, not far from Duluth, is 1026 feet—the maximum depth of the lake, as shown by the hydrography.

The depth of the lake at three or four miles from the shore is generally as great as in its centre; in fact, it is often deeper near the shore on its north-western side. However, about the Apostle islands, between the Pictured rocks and St. Mary's river, and in some of the bays, the waters are shallower than in the open lake, with their floors more or less gradually sloping as they recede from the land. As is well known, the lake is generally surrounded by crystalline or metamorphic rocks, which rise from several hundred to even twelve or thirteen hundred feet above its surface. In short, the near shore hydrography simply shows that the present submerged margins of the lake are composed of the bases of the same rugged hills that surround it above the water. The margin of this mountain-bound basin forms a strong contrast with its floor, which, at most, is only a slightly undulating plane, extending for nearly its whole length and often for little less than its breadth, excepting in its south-eastern portion and some other places referred to above. In fact, the lake bottom is quite as level as most extensive planes which are now subjected to sub-aërial action.

That this great plane is not covered with any great depth of drift-deposit (excepting locally) appears evident on examining the character of the bottom of the lake in the soundings just off Keweenaw point, and those to the northward. In the various localities hard and rocky bottoms are alike found in both places, at the same depths, so frequently that they cannot be regarded as only rocky eminences protruding through the silt covered bottom which is generally observed.

The general direction of the deepest channel, for more than 200 miles along the north-western margin of the lake, appears to point to a river

course in the region of its south-western extremity, and the few deeper holes to have been produced by some receding cascade from the adjacent shore to which there appears to be a transverse deep channel south of the mouth of Gooseberry river.

Again, Prof. N. H. Winchell calls attention to the depression in the low country between the Chocolate river (east of Marquette), and Train bay (near the Pictured rocks), as the only place where there could have been connection between the basins of Lakes Superior and Michigan. It may be remarked that some of the deeper soundings put in towards this portion of the coast, whilst, to the westward and eastward, the present lake bottom slopes more gradually. The soundings, however, that are near the shore, show a rocky bottom, excepting north of Laughing Fish point (Sable river), and along a narrow channel north of the mouth of Chocolate river. The lake is very shallow for some distance westward of the St. Mary's river.

Lake Michigan. This lake may be said to consist of a broad long plane, the northern half having a mean depth of about 600 feet, whilst the soundings in the southern half are not much more than half that measurement. The deepest sounding recorded is 870 feet, in the latitude of the southern end of Green bay. Throughout the whole length, the lake appears to be traversed by a deep channel, and in the northern end by more than one. Although the pitch of the bottom from the shore line is more or less gradual—generally less than 40 feet in a mile—yet, along the eastern side there is a precipitous escarpment extending for a considerable distance, which in one place suddenly descends, in a horizontal line of little over a mile, from 17 to 93 fathoms, or 456 feet, and increases 60 feet more in the distance of another mile.

The conspicuous channels in the submerged plane extend far northward to near the end of the lake. An interesting sounding east of the mouth of the Manistique river shows a depth of 448 feet, at a distance of two miles from the shore, whilst all the adjacent depths do not exceed 11 fathoms. This appears to be a continuation of the deep soundings, ten miles to the southward, but the surrounding lake bottom is covered with drift to a great depth, wherever the Niagara limestones have been removed. It is more than probable that this great depth is in a rock-bound channel of an ancient water course, which elsewhere has been filled with drift. It seems probable that it was a portion of a buried channel extending through the valley of the Manistique lakes to the depression in the country south of Lake Superior, alluded to above, and formed a Preglacial connection between the valleys of Lakes Superior and Michigan. Prof. Winchell regards the valley between the two lakes along the Chocolate and White Fish rivers (the latter emptying into Little Baie De Noc), as indicating the ancient connection. This route seems less favorable, as both Little Baie de Noc and Green bay are shallow compared with Lake Michigan, for the greatest depth, which is near an outlet through Portes des Mortes, is only 32 fathoms, whilst generally the bay does not exceed 100 feet.

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Green bay is separated from Lake Michigan by a Niagara escarpment facing the westward, and rising two or three hundred feet above the waters. There appears not to have been any closer connections between these two basins at any previous time than at present, excepting when the waters were at a higher level. We are told that from Green bay for 400 miles to the Mississippi river, a broad, low depression occurs in the country and may have been a former outlet for Lake Superior. This valley is filled with drift even if it ever had a sufficient depth.*

Grand Traverse bay has a considerable depth in both of its branches, especially in the eastern. Here we find depths to 612 feet, whilst its northern mouth is now filled, so that it does not exceed 120 feet.

The north eastern portion of the basin of Lake Michigan has a general depth of less than 100 feet, but with deeper channels running through it. Many of the soundings about the Straits of Mackinac show a rocky bottom at no great depths. The channel between the 10-fathom contour margins is not much more than a mile and a half wide, and though generally shallower, contains a hole 252 feet deep. In proceeding outward, the deepest channel passes northward of Mackinac island, having a depth not exceeding 216 feet, and a width of less than a mile.

Again, a depression of the country extends from near Chicago, on Lake Michigan, towards the Mississippi river, which, in some places, is known to be filled with drift to a depth of more than 200 feet, according to Dr. Newberry. This is along the Illinois river, whose valley is from two to ten miles wide ; whose mouth is 200 feet lower than Lake Michigan ; and whose upper streams, near Chicago, are only a few feet higher than the neighboring lake.

Lakes Huron and St. Clair. Of these water basins we can make four divisions. The first section may be made to include the shallow basin south of a line drawn from Thunder bay, or Presqu' Ile, to Kincardine, in Canada, and Lake St. Clair. The second basin comprises the deep channels of Lake Huron, and extends northward to the Manitoulin islands and the Indian peninsula ; the third, the north channel between the Manitoulin islands and the Huronian hills, to the northward ; the fourth, Georgian bay proper.

The first of these divisions is represented by shallow water, seldom thirty-

* Since writing the above, I have fortunately been able to see General Warren's Report on the Transportation Route from the Mississippi river to Green bay (*via* the Wisconsin and Fox rivers). In this report we find that the bottom of the valley alluded to in the text has a maximum height of 208.8 feet above Green bay, and also that Lake Winnebago (on Fox river) is 169 feet above the same water. This small lake discharges by the Fox river, which flows over hard limestones down a series of rapids. Therefore Green bay never discharged its waters into the Mississippi river, and this depression in the country between the Great river and Lake Michigan (the Green bay portion) was not a former outlet of Lake Superior, since it was within about 200 feet of the present level. This fact strengthens the probable correctness of the suggestion that Lake Superior emptied into the northern end of Lake Michigan directly. Also, Green bay has evidently the character of a fiord. The outlet of Lake Michigan could only have been by the low country along the Illinois river.

five fathoms deep, but with a channel of about fifty fathoms depth running through it, towards the direction of the north angle of the Au Sable river, near Brewster's mills. Saginaw bay, belonging to this section, is like Green bay, shallow even at its mouth, where it is less than 100 feet deep.

Lake St. Clair is a flat plane, with its bed varying from 18 to 21 feet below its surface, and is altogether modern.

At Detroit the drift is 130 feet deep. The three south-western counties of Ontario are low and flat, and covered with drift varying generally from 50 to 100 feet in thickness below the level of Lake Erie. In places it is known to be absent to a depth of 200 feet below the same lake in portions of a buried channel to be noticed below. In fact, all the evidence appears to show that the southern end of Lake Huron and the western end of Lake Erie, with the intervening region, constituted one plane underlaid by a considerable depth of Erian shales, reposing on the thick development of Coniferous limestone, and traversed by deep channels running through it.

The section of Lake Huron under consideration is mostly excavated out of Upper Erian shales in a direction at right angles to the trend of the formations. The denuding action was lessened when the waters in the deeper northern part of the lake subsided to a level having a southern margin bounded by hard Coniferous limestone, covered to no very great depth with Upper Erian shales subjected to only sub-aërial action—the whole traversed with water courses in deep channels.

The second division into which, for convenience, I have made of Lake Huron, is that portion between the line drawn from Presqu' Ile to Kincardine, and the Manitoulin islands to the northward. This is the deepest portion of the lake and extends in a direction running from north-west to south-east. It consists of a broad plane traversed by several deep channels. The average depth of this plane below the surface of the lake does not exceed 75 fathoms, although there are channels much deeper, one of which is represented by a depth of 117 fathoms. There is also one isolated sounding, which reaches 125 fathoms or 750 feet, this being the deepest spot known.

The deeper channels appear to lead from the northern portions of the lake, and unite as they proceed southward, being separated by elevations indicating peninsulas or islands. Two of the principal channels appear to proceed from Mississagua strait (between Manitoulin and Cockburn islands), and from south of Manitoulin island, eastward of the Duck islands. However, the channels in the marginal portions of the lake are generally more obscured by drift or silt than towards the central waters. The channel, if such you can call it, proceeding from the Mackinaw straits is of inferior depth to those leading from the more northern end of the lake.

This portion of the lake is excavated out of the rocks of the various formations from the Niagara to the Coniferous limestones. But most largely out of the more or less soft rocks of the Onondaga group, along the strike of these formations, thus giving the eroding agencies the power of removing the softer basal rocks, and of producing an escarpment of the Conifer-

ous limestone looking to the northward, until it was finally undermined, and worn back to its present position, submerged beneath the shallower waters of the southern portion of the lake, or buried in drift deposits.

On the northern side, the lake has not made so much encroachment, as it is bounded by the hard Niagara limestones of the Manitoulin islands, and the Indian peninsula of Canada, the strata dipping down beneath the lake. Yet it must be noticed that these rocky shores are indented by numerous deep bays transverse to their directions.

The North Channel. This is generally a shallow water, the greatest depth being only 204 feet. To the northward, we have the Huronian rocks forming the boundary. The islands, especially towards the eastward, and near the whole north shore, are generally composed of Trenton limestone.

The southern margin of the channel, bounded by Manitoulin and the other islands, is often composed of Hudson river, more or less, shaly rocks, overlaid by the Niagara limestones (where not removed by denudation), constituting an escarpment facing the northward. In fact, the whole of the north channel is principally scooped out of the Hudson River Formation, which attains a considerable thickness in this region.

Dr. Robert Bell states that he has observed fifteen anticlinal folds traversing the group of the Manitoulin islands; and it is in these that we find the great indentations, and lakes in the islands, as well as the straits which separate them. Doubtless many of the southern ends of the Manitoulin lakes and channels are filled with drift. For example, the mouth of South bay is only 33 feet deep, whilst the upper portion is generally deep, one place giving a sounding of 156 feet.

In fact, the north channel may be considered as a broad continuation of the Spanish river westward. The Mississagua river points directly to Mississagua straits, which are 204 feet deep, as deep as any part of the channel itself. Thessalon river has a direction towards False Bay De Tour, which is 186 feet deep. Vermilion river flows amongst the islands west of Cloche mountains and probably had a connection to Lake Huron through some of the buried channels across Manitoulin islands, as between Manitouaning and South bays.

The narrow channel between the peninsula of Cloche mountains and Manitoulin island is less than 60 feet deep and appears to be a modern connection with Georgian bay.

Georgian Bay. The eastern and northern margins of this bay are composed of crystalline rocks; the south-eastern, of Trenton limestone; whilst the western is made up of the Hudson River shales capped with the Niagara limestone, on the Indian peninsula and Manitoulin island. This basin is principally excavated out of the Utica shale, and the somewhat harder rocks of the Hudson River Formation. It lies along the junction of the various formations, and thus on the removal of the lower soft layers of rock, an escarpment was produced which has subsequently and slowly continued to be undermined.

In the channels connecting this bay with Lake Huron, there are many

small islands separated by shallow water. Yet in one place there are two deep soundings reaching 51 and 42 fathoms. The bay itself is much deeper than these passages, for there is an escarpment submerged to a depth of 498 feet immediately off the Indian peninsula, at Cabot's Head, which is itself 324 feet above the bay. This peninsula is deeply indented with bays or fiords.

There is a depression from the southern end of the bay, through the valley occupied by Simcoe, Balsom, Rice and other lakes, to the Trent river, emptying into the Bay of Quinté, an arm of Lake Ontario. This will be alluded to again.

IV. The Buried River Channel in the Dundas Valley and its Extensions.

That the Dundas valley is that of an ancient river valley now buried to a great depth with the *débris* produced in the Ice Age, becomes apparent on a careful study of the region. However, until a key was discovered the mystery of its origin was found to be very obscure. My own labors at studying this region may fairly be stated as the first systematic attempts at the solution of the present configuration of the western end of Lake Ontario and the adjacent valley. Assertions have been made that it was scooped out by a glacier, but this wild hypothesis was only a statement made without any regard to facts.

From the description of the topography, given in Section II, of this paper, it will be seen that the apparent length of the rock-bound valley is six miles, with a width of over two miles; then it widens suddenly to four miles (with concave curves on both sides), after which it gradually increases in width as it opens into Lake Ontario. The direction of the axis of the valley is about N. 70° E. The summit edges of the rock-walls on both sides are sharply angular and not rounded or truncated. This angularity is not due to frost action since the Ice Age, to any extent, as is shown by the character of the talus. The rocks of the summit are frequently covered with ice markings, but I am not aware of any locality where they have been observed as being parallel with the true direction of the valley, but on all sides one can observe them (sometimes at only small angles of less than 30 degrees) making conspicuous angles with its axis. One exception may be made to this statement. On a projecting ledge of Clinton limestone, at Russel's quarry, near Hamilton, at a height of 254 feet above the lake, and 134 feet below the summit of the "mountain," after the removal of some talus, I observed that the surface was polished, but with scratches so faint that they could scarcely be compared with those of fine sandpaper on wood; and the direction, if determinable, was parallel with the overhanging escarpment. There are many tributary *cañons*, which are evidently of greater antiquity than the Ice Age, which could not have excavated by the present streams, and are at all sorts of directions compared with the striated surface of the country.

The topography of the lower lake regions precludes the idea of a glacier flowing down the valley to the north-eastward. Again, as the direc-

tion of the ice was towards the south-west, the waters from the melting glaciers could scarcely flow up an escarpment many hundreds of feet in height. Even if the Niagara escarpment did not exist elsewhere, the non-parallelism of the striæ, and edges of the escarpment with their angular summits, is sufficient to prove the non-glacial origin of the valley in the hard limestone rocks. Moreover, at the eastern end of the narrower portion of the valley, there are two concave curves facing the lake, which of necessity would have been removed if such a gigantic grinding agent had been moving up the valley.

This glacier-origin of the valley being an absolutely untenable hypothesis, I sought for some fluviatile agent capable of effecting the present configuration of the region. At the time, no idea occurred that even the great valley of the present is only a miserable remnant of one of gigantic proportions obscured by hundreds of feet of drift. The question arose, could Lake Erie have ever emptied by this valley? This suggestion did not hold its ground for any length of time, because the present levels are all too high. Near Galt, the traces of the true origin first presented themselves. A branch of the Great Western Railway extends from Galt southward for about four miles in the valley of the Grand river, after which, without making any important ascent, it passes into the broad older valley, described above as that in which Fairchild's creek now flows. After a careful examination of the region, and of the railway levels, I came to the conclusion that this was an old buried valley. It then became apparent that if the Grand river had occupied the site of the Fairchild's creek, that the latter probably flowed down the Dundas valley, and that the Grand river, being one of the largest of the rivers of Ontario, might have been a sufficient cause for the great excavation at the western end of Lake Ontario. Having procured all the levels that bore on the subject which were available, it became necessary to connect several places myself by instrumental measurements, which work was accomplished last July, with the aid of Prof. Wilkins. As the whole floor of Niagara limestones is absent, as has previously been shown, the proof that the ancient Grand river flowed down the Dundas valley was completed, and of this discovery there was published a local notice last August. Significant and interesting as this fact was, relative to the change of systems in our Canadian drainage, a still more important issue was involved. When taking the levels between the Dundas valley (modern) and the Grand river, it was found that the whole calcareous floor was removed from a basin several miles in width, and that all the wells were sunk to a considerable depth in the drift before water could be obtained. On glancing at the map it will be seen that the Grand river from Brantford to Seneca meanders through a broad course, which in its ancient basin is several miles in width, but that from Seneca the valley is narrower, and the course of the stream more direct, as far as Cayuga. At Seneca the valley is two miles wide, and seventy-five feet deep. Also the bed of the Grand river at Seneca is in drift which is only 37 feet above the lake into which it now empties. As has been pointed out in the section

on the topography, this broad valley continues to Cayuga within a few miles of the lake, whence its former probable course was by a nearly direct line to Lake Erie, now filled with drift, near the present bend in the river towards the eastward. At Cayuga, the rock beneath the drift-bed of the river is below the lake level, on the margin of its ancient valley. (See note, Section II.)

Having observed the connection between the Dundas valley, Grand river and Lake Erie, it dawned on me that I had established the knowledge of a channel having a very important bearing on the surface geology of the lake region. It now became apparent that Lake Erie had flowed by the Grand river reversed to a point west or north-west of Seneca, and thence by the Dundas valley into Lake Ontario; also that the upper waters of the Grand river, previously discovered as passing down the Dundas valley, were really tributary to the outlet of Lake Erie, and joined it somewhere south of Harrisburg; and that the basin between the Brantford (and the Grand river of to-day) and the Great Western Railway, at Copetown, formed an expanded lakelet along the course of the ancient outlet of Lake Erie, scooped out of the softer rocks of the Onondaga Formation before noticed. As the waters excavated a bed in a deeper channel, of course this lakelet would become an expanded and depressed valley, such as we often see amongst the hills of drift, at a short distance westward of Dundas. Possibly the Grand river divided and flowed around an island, the western side of which is occupied now by the town of Paris. At any rate, Neith's creek, at that town formed a large tributary to the river then flowing down to Lake Ontario.

Along the course from Cayuga to Lake Ontario all obstacles to the outlet of Lake Erie appear to be removed. But along the present course of the Grand river, eastward of Cayuga, the waters flow over Coniferous limestone. But this difficulty is removed on observing that the river, filled with drift, approaches Lake Erie to within a direct distance of about six miles, but that at this place it leaves its southward course and also its conspicuous valley and flows eastward, in the same manner as the Niagara river, above the Whirlpool, left its old choked-up outlet by the valley of St. David, and cleaned out a new channel for itself through several miles, in hard rock, from Queenston southward.

We have recently seen by a note in the second section of this paper, that the Grand River bed is near the eastern margin of its ancient valley at Cayuga. From northward of this town, at about half a mile to the westward of the river, a deep depression in the drift indicates the deeper portion of the ancient river as it left the modern channel direct for the Lake Erie basin. Also along this route the hard rock is known to be absent to a depth below the surface of Lake Erie.

In Ohio, the Geological Survey considers that Maumee river emptied into the Wabash. If the waters of Lake Erie ever passed by this route into the Mississippi river when they were at no higher level than at present, then there must be a channel buried to a depth reaching at least 170 feet above

the lake, as that is the elevation of the divide between the upper waters of these two rivers.

The outlet of Lake Erie, indicated in this paper, is known at many places along its route to have no rock-bed for a distance below the surface of the higher lake, and to a probable depth shown below sufficiently great to empty Lake Huron.

Again, Mr. Carll has shown that the Allegheny drainage passed near Dunkirk into the Erie basin at a place just opposite to its outlet, as indicated by the present writer.

Much of the Dundas valley is underlaid by stratified Erie clay, which is known to extend to a depth of 60 feet below the surface of Lake Ontario, according to Dr. Robert Bell. In the upper part of the valley, streams have exposed some deposits of unstratified clay filled with angular shingle,

Fig. 2.

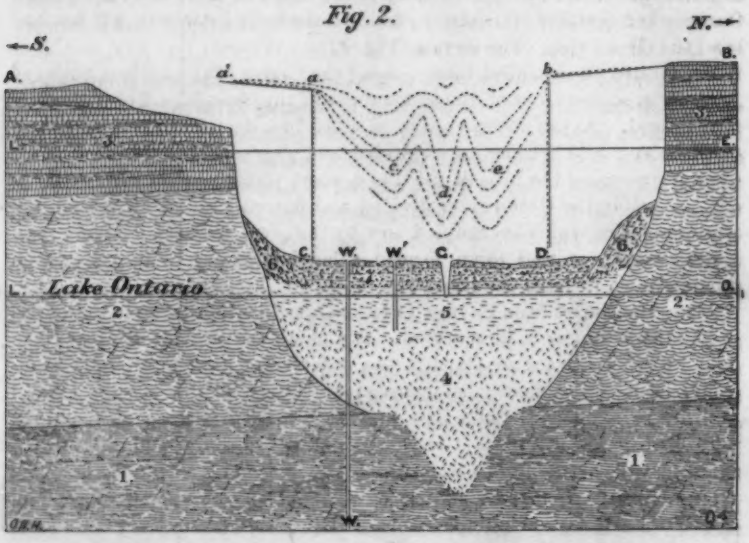

FIG. 2.—1. Hudson River Formation; 2. Medina shales; 3. Niagara and Clinton dolomites with some shales. A, C, D, B, modern valley at meridian of Burlington Heights; a, C, D, b, modern valley at meridian of Dundas; a, c, d, e, b, sections across, deeply excavated in beds of streams in western part of the Dundas valley; 4. Boulder clay filling ancient valley; 5. Erie clay; 6. Talus from sides of escarpment; 7. Old beach, 108 feet above lake at Burlington Heights. G. Desjardin's canal leading from Dundas marsh to Burlington bay; W, W, well at Royal Hotel, Hamilton; W', another well at Dundas; L, O, level of Lake Ontario; L, E, level of Lake Erie. Horizontal scale, 2 miles to an inch; vertical scale, 400 feet to an inch.

derived from the thin beds of limestone forming the upper portion of the Niagara Formation. In the eastern portion of the valley, the Erie clay is overlaid unconformably by brown Saugeen clay or loam (stratified). In the upper portions of the valley the hills are capped by brown clays or

sands. But along some of the hillsides excavated so deeply in the drift, we find old beaches resting unconformably on boulder clay.

Near the centre of the city of Hamilton, in the wider portion of the Dundas valley, a well was sunk to the depth of over 1000 feet. This well revealed a most interesting fact. Though known to me several years ago, I did not apply it until recently to its true bearing, since discovering the origin of the Dundas valley. Mr. J. M. Williams sunk this well, at the Royal Hotel, in Hamilton. He told me several years ago that he had to sink through 290 feet of boulders, before coming to hard rock, thus causing the outlay of a large sum of money in excess of his calculations. Unfortunately, this well-record has been lost by fire. At that time, the fact was so fresh in his memory (improved by the extraordinary cost of the well) that his statement could be relied on, being experienced in well-borings. The mouth of this well is 63 feet above Lake Ontario, and therefore the hard rocks are absent for a depth of 227 feet below the lake surface. See section, Fig. 2.

As the valley is five miles wide at this place, and as the well is only about one mile distant from its southern side, it becomes apparent that the valley in the centre must have been much deeper. Moreover, if we produce the southern side of that portion of the valley, which is over two miles wide, we find that the well is less than a quarter of a mile away from it. Now if we connect the top of the Medina shales (240 feet above Lake Ontario) with the base of the drift in the well, and produce it to the centre of the valley, it would indicate a central depth of over 500 feet. At the base of the drift there are nearly fifty feet of Medina shales, below which are the Hudson River rocks (more or less calcareous and arenaceous, mixed with the shales). This harder formation along the bed of a river would be less extensively removed by aqueous action than the overlying Medina shales, especially as the pitch of the waters would be much lessened. This graphic method of calculation seems as perfectly admissible here as it does in determining other constants of nature. However, I have placed the estimated depth in the section at about 70 fathoms below the lake surface, which depth is perfectly compatible with the soundings of the lake of no very great distance to the eastward. Even this depth gives only very gentle slopes from the sides of the river valley. It should be remarked that Burlington bay is excavated from stratified clays in places to a depth of 78 feet. But this water is silting up comparatively quickly.

Now we have seen that the deep excavation in the Dundas valley and westward is cut through more than 250 feet of Niagara and Clinton rocks, mostly of limestone, and to a depth in the Medina shales, so that the total known depth of the *cañon* is 743 feet, but with a calculated depth in the middle of the channel of about 1000 feet. This depth for a *cañon* is not extraordinary for Eastern America. In Tennessee there are river valleys excavated to a depth of 1600 feet, and in Pennsylvania Mr. Carll reports others to be equally deep.

Again, this Preglacial river explains the cause of the present topography

of the western end of Lake Ontario. The drainage by this river swept past the foot of the submerged escarpment of Lake Ontario, described in preceding pages, until it passed the meridian of Oswego.

With such an outlet, and with the ancient Grand River valley buried to an equal depth, we have an easy solution to the problem of the drainage of Lake Erie. See section, Fig. 3.

Fig. 3.

Section of Grand River Valley at Seneca.

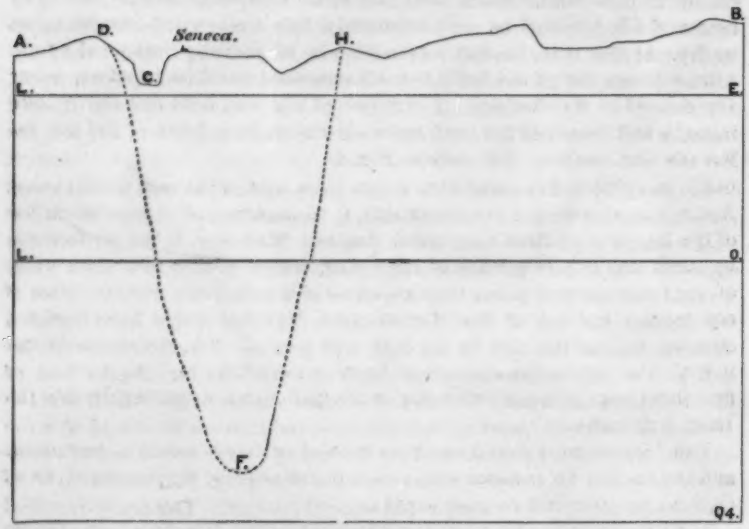

FIG. 3.—Section of Grand River valley at Seneca. A, D, C, H, B, is the profile of the H. & N. W. Railway; horizontal distance, 2 miles to an inch; vertical, 400 feet to an inch. C, represents position of Grand river; D, C, H, valley two miles wide and with maximum depth of 75 feet. L, E, level of Lake Erie; L, O, level of Lake Ontario; D, F, H, probable depth of buried valley.

Attention has been called in this paper to the deepest portion of Lake Erie being southward of Haldimand county, and about the end of Long point, and extending transversely towards the Pennsylvania shore.

So far, our remarks have applied to Canada. If we turn towards the American shore, we will see that the observations made there go very strongly in support of what has been written.

Several years since Dr. Newberry, Mr. Gilbert, and others, called attention to the deeply buried valleys of the Cuyahoga, Chagrin, Grand, Maumee and other rivers in Ohio, which emptied into Lake Erie much below their present levels. The Cuyahoga has its channel buried to a depth of 228 feet below the surface of Lake Erie of our time, whilst the deepest water in the neighboring portion of the lake is less than a hundred feet.

In Report III, of the Pennsylvania Geological Survey, issued in November, 1880, Mr. John F. Carll published excellent maps of the Preglacial drainage of that State and the neighboring portions of the adjoining States. This report on the Preglacial rivers is the result of five years' labors in the oil regions, and many of Mr. Carll's results have been derived from the facts made known by the borings for mineral oil.

Besides calling attention to the very deep valleys of erosion amongst the mountains, Mr. Carll has shown that in the oil regions the river valleys are frequently filled with drift to a depth of from 200 to 450 feet. In fact, nearly all the present rivers flow over beds deeply filled with drift. The map of the Preglacial drainage shows that the upper waters of the Allegheny emptied by the Cassadaga river, reversed, into Lake Erie, near Dunkirk, and had for tributaries many other streams now flowing southward; for example, the Conewango. These streams drained an area of 4000 miles, which now sends its surplus waters to the Ohio river. Again, the French and other rivers, now emptying southward from the Conneaut basin, emptied in Preglacial times into Lake Erie, westward of Erie city. Again, the Chenango, Connoquenessing, Mahoning and other tributaries of the Beaver river (itself now emptying into the Ohio) flowed northward, by the Mahoning river reversed, into the State of Ohio, to near the sources of the Grand and Cuyahoga rivers. Hence Mr. Carll did not continue its course, on the map, but from the study of the levels and character of the country, as described by the Geological Survey of Ohio, I have connected it with the Grand river of Ohio, as represented on my map. Thus we find three large areas now flowing southward formerly emptying into the Lake Erie basin.

The deepest portion of Lake Erie is between these ancient river mouths and the ancient *débouchement* of the Erie drainage by the Grand river of Ontario, as described in these pages.

Thus we have shown a consecutive system of drainage of the former waters of the buried channels into Lake Ontario, and thence running along the foot of the submerged escarpment of the latter lake to its eastern end, receiving the Genesee and other large rivers along its course. In a portion of the present notes, the writer will endeavor to make known still further the buried channels of Ontario, which exist between Lakes Huron and Erie when treating of the origin of these lakes.

The remaining portion of this paper will be devoted to the subject of the origin of our great lakes. The writer does not wish to enter here into the discussion of the drift deposits, and their origin at the present time, but to reserve it until the final report on the surface geology of the Western End of Lake Ontario. Yet the facts brought to light in this study have an important bearing on the great controversy of the Glacial Drift, and lead one to the conclusion that the Ultra-Glacial theorists stand on uncertain grounds.

V. Origin of our Lower Great Lakes.

On a former page of this paper attention has been called to Prof. Winchell's observations of an outlet from Lake Superior by way of Little Baie

de Noc, and also my theoretical divergence slightly from this view. That an outlet did exist somewhere in the region between Lakes Superior and Michigan, seems certain, of course, we do not know to what depth, but from the evidence brought forward from the soundings in the northern end of Michigan lake to at least half the depth of our greatest lake, and probably to the whole depth.

There appears also to have been an outlet from Lake Michigan, near Chicago, emptying into the Mississippi river. These two lakes both lie outside of the study of the present paper, but before passing to the other lakes, let us note certain facts which present themselves to the view of the writer. Without taking up the bibliography of the subject, it may be stated that some have regarded the origin of the lakes as being due, to a greater or less extent, to the geological valley, formed at an earlier date. Of our five great lakes, certainly not more than one can possibly come into this category—that is Lake Superior. Not even the northern side of the north channel of Lake Huron, bordered by crystalline rocks, could be included. The writer even doubts that Lake Superior is essentially anything more than a valley of erosion, and if it be, it remains to be proven. Yet its position was probably determined to a greater or less extent by the orography of the region, and its excavation appears to have been principally by erosion. Although the lake is in the region of very ancient continental oscillations, there are no evidences of different elevations, and subsidences in different portions of the lake basins. Five years ago, I pointed out that Superior was eminently a region liable to atmospheric erosion, as the great volcanic seat situated about the Keeweenaw Point, in Presilurian times, would tend to weaken the strata. All who have made a study of the three miles in thickness of the copper-bearing rocks, pitched at various angles, whether on the northern or southern shores, and crossed by numerous faults, know that they are particularly liable to irregular atmospheric decay. As an example, we have remaining an excellent case in that in which Portage lake lies, now a valley transversely situated in the Keeweenaw hills, and excavated to a depth of six or eight hundred feet. In the narrow channel between Houghton and Hancock the waters are 60 feet deep and underlaid by a considerable depth of silt.

According to both Professors Dana and Whitney's explanation, fiords are valleys of erosion, when the land was at a higher level; but as a necessary condition, high hills or mountains should be near a shore, so as to give pitch to the descending waters; from this definition we can fairly consider most of the bays of Lake Superior, Lake Huron, and those about the Niagara escarpment in the region of the Green bay extension of Lake Michigan, as belonging to this category.

Lake Michigan is nearly deep enough to remove all the waters of Lake Superior. Such deep places as the 171-fathom hole north-east of Duluth could easily be produced by a cataract, the same as the water in the Niagara river is so much deeper than its rock-bound outlet into Lake Ontario. Moreover, the peculiar form of the south-western extension of Lake Supe-

rior can only be explained as having in part been produced by water, running in one direction or the other, as the St. Louis river now empties, at Duluth.

That the other lakes are not occasioned by a geological depression or elevation can be easily seen, as they are exclusively excavated from stratified rocks lying almost flat, perhaps dipping in no place at higher angles than 40 feet in a mile.

The North channel and Georgian bay of Lake Huron belong to a separate category from the rest of the lakes. I do not deny, as far as Lake Ontario and the north-eastern half of Lake Huron are concerned—both of which are excavated at the junction of hard and soft strata and parallel with their trend—that they might have had the direction of their first rivers determined by continental elevation. Yet, in no other respect are these lakes now occupying geological valleys.

Dr. Newberry is of the opinion that the valley of Lake Michigan was separated from that of Huron at the Straits of Mackinac, even at a comparatively recent period. I concur with this view entirely. Lake Michigan is 22 fathoms deeper than Lake Huron, and therefore could in no natural way have ever been entirely drained by the latter lake. There is no evidence of local subsidence, and the glacier theory is absolutely untenable, as will be seen further on. In the Beach Epoch of the Ice Age this separation seems to have existed, as it is stated that the highest beach north of Lake Michigan is 65 feet, whilst that on the island of Mackinac is more than 250 feet above these waters. We know that there are several correspondingly high beaches along the margins of the basin, including the three great lower lakes.

Thus we can cut off the two western waters of the great chain of American lakes from our subject and leave them for future inquiry.

Whether the above named outlets of Superior and Michigan are sufficiently deep to have drained their basins, at the time when we know that the Mississippi valley was several hundred feet higher than at present, remains to be shown.

The writer will now deal with those waters to the eastward, and see what difficulties have been removed and what still remain, for Lake Ontario is nearly a hundred feet deeper than the deepest sounding of any of our upper lakes.

Dr. Newberry prophesied that an outlet for Lake Erie into Lake Ontario would be discovered near the Welland canal. This outlet in an unexpected position I have discovered, and in a position which explains more perfectly the cause of the topography of Lake Ontario than any that could have been discovered forty miles to the eastward. Moreover, I have shown that its depth is not only sufficient to empty Dr. Newberry's deep Cuyahoga (228 feet below Lake Erie), or the ancient rivers, worked out by Mr. Carll (the most systematic study of fluviatile geology that has been done on this continent), but also sufficiently deep to empty the deepest waters of Lake Huron into Lake Ontario.

When was the advent of such a drainage system for this continent? Some of our American friends, who have advocated the sub-ærial and fluviatile origin of the lakes, have placed it back to the Devonian Age. About the commencement, we know nothing. It would be safer to place it after the Palæozoic time, for probably some portions of the Province of Ontario were covered with carboniferous deposits, as well as Michigan and Ohio, which have subsequently been removed by denudation.

Outlet of Lake Huron. The south-western countries of Ontario are dotted with borings for oil. From these well-records, one can draw only a single conclusion, that they are underlaid by drift (mostly stratified and perhaps wholly) to a depth of not more than 100 feet below the surface of Lake Erie, and that generally to not more than 50 feet. There are deeper borings in drift, it is true, but these may be fairly considered as in buried channels. For instance, at Detroit the drift is 130 feet deep. Again, at Port Stanley, it is 150 feet below the surface of the lake; at Vienna it is 200 feet below Lake Erie. If we draw a line from near the northern angle of the Au Sable river (of the south) to east of Vienna, we have a boundary to the deeply drift filled basin of south-western Ontario; for at Tilsonburg, St. Mary's and elsewhere (just east of this line) the hard limestones come to near the surface of the country much above the level of Lake Erie. Excepting a few shales, at Kettle Point, all the south-eastern shores of this lake are composed of sand dunes and other Post-Tertiary deposits. The upper portion of the Thames and Au Sable rivers are in conspicuously Preglacial beds filled with drift. The Au Sable, after turning northward, continues in a partly re-excavated valley to a point within a mile of Lake Huron, and then turns at an acute angle and runs for a dozen miles southward parallel, and very close, to the lake before emptying into it.

Now, if we look at the large geological map of Canada, it will be seen that the region underlaid by Upper Devonian shales extends south-eastward from Lake Huron, forming a narrow belt across the country to Lake Erie. Dr. Hunt has shown, that in places these shales are four or five hundred feet thick, beneath the drift. On a careful study, it will be seen that these south-western countries of Ontario simply formed a continuation of the valley of Lake Erie to Lake Huron, or *vice versa*. The depth of this valley, or plane, as we have seen, does not exceed 100 feet below the lake level (Erie), except in channels, and generally less than that depth; while the waters in adjacent portions of Lake Erie vary in depth from 30 feet, at the western end, to a maxium depth of 84 feet further eastward, where removed from the mass of modern sediments now being brought down by the western rivers. From these facts, but one conclusion can be drawn, and that is, the deepest western portion of Lake Erie is not silted up to a greater depth than the difference between its soundings and 100 feet; except in channels, such as the Cuyahoga.

From these figures it will be seen that the country including the greater portion of Lake Erie, the south-western counties of Ontario, and the southern portion of Lake Huron formed one nearly uniform plane, in shale-

rocks, which, however, gradually sloped both to the northward and eastward towards the deepest portions of the lakes. From the borings, we see that there were channels, and I think that we are furnished with the data for pointing out where the outlet of Huron formerly flowed, even to a depth sufficiently great to drain the deepest portion of the lake, although filled with some sediment. That portion of the Au Sable flowing northward in an old buried valley, and then turning southward, indicates a portion of the ancient outlet. The channel having been dammed in the Ice Age, has caused the modern river to flow in the capricious manner indicated on the map. This portion of the river reversed, formed an ancient outlet for Lake Huron, and flowed to its south-western angle, then turning eastward, the direction (with gentle curves) was south of eastward across the country to Lake Erie, having Port Stanley on its right, and Vienna on its left bank. It is known that the channel at the former place was 150 feet, and at the latter 200 feet below Lake Erie, and with a sufficient distance between these places to have permitted of a valley four times that depth, even in the Hamilton shales, and underlying Coniferous limestones. At a distance of only a few miles eastward of this line, the Coniferous limestone comes to near the surface of the country, and is exposed by several modern streams. The upper portion of the Thames, the eastern branches of the Au Sable, and other streams belong to Preglacial times with buried channels, were tributaries to this old outlet.

Throughout the south-western counties generally there is a broad belt underlaid by several hundred feet of Devonian rocks (mostly of shale of the Hamilton group), beneath the drift deposits, which cover them to a depth of from 50 to 100 feet.

Two things along this route support the theory that this channel, known to be 200 feet deep (below Lake Erie) and able to drain half of the surface of Lake Huron, was of more gigantic proportions, is the nature of the drift near Port Stanley, and the configurations and soundings of Lake Erie. Near Port Stanley, the drift is piled up much deeper than it is usually found in this section of the country, reaching 150 feet above the lake. From whichever cause (glacier or iceberg), it is just what would be expected along the margin of a valley against which drift-bearing ice would be passing. The other indication is, that if we draw a line from a short distance north of Port Stanley to southward of Vienna (the direction of the valley), it forms a continuation of a nearly direct portion of the present shore, curving slightly to Long point, just off which the deepest portion of the lake is found, and around which the channel turns, to the Grand river of Canada. It cannot be justly said that the present configuration of the lake is independent of its Preglacial form. Nor can it be said that the lake is generally silted up to great depths, except in channels, for any such statement is unwarranted by facts, as I have shown from the analogy between the bottom of the western end of the lake, and the south-western counties, to be improbable.

Course of Preglacial Rivers. We are now able to construct an approximately true river map from Lake Huron to the eastern end of Lake Ontario.

The streams ran from the north and west of Lake Huron, south-eastward towards Goderich; thence southward, and entered the Au Sable near its northern angle; it turned eastward, near the southern angle of the same river, and with a gentle sweep, having Vienna on the left and Port Stanley on the right bank (receiving the upper-waters of the Au Sable and Thames as tributaries), it passed Long point, flowing near the present Canadian shore, and entering the Grand river (reversed) south of Cayuga; afterwards it passed down the Dundas valley towards north-east, into the basin of Ontario, and then along the foot of the buried Hudson River escarpment to near Oswego.

Along its course, it received, probably, a small stream from near Detroit, the Maumee, Sandusky, Chagrin, Cuyahoga, Grand (of Ohio, and its tributary, the Mahoning), Conneaut, Allegheny, and other rivers from the American States, and afterwards the Genesee and various other streams in its course through the basin of Ontario.

The rate at which this basin was excavated, of course depended on the wear of the limestone rocks after entering the Grand river. But as this was very slow, the softer shaly rocks would gradually be worn down, and the basin of these lakes, in the shaly rocks, across their beds, would be greatly widened, as we see it.

No great pitch in the rivers would be required to occasion a flow of the waters, a very few inches in the mile would suffice. If we observe the deepest portions of Lakes Huron and Ontario, we have a difference in altitude of 360 feet (both being below sea-level) in 400 miles along the route indicated, whilst probably there were lake-expansions along the course, thus causing the fall to be confined to a few places, especially through the Dundas Valley, in the form of a series of rapids after the capping limestones had been removed.

Excavation of Lake Basins. Having seen the course of the Preglacial drainage, let us ask how the broad lake troughs could be excavated. First let us look at Lake Ontario.

The river coming down the Dundas valley flowed originally at near the out-crop of the Niagara limestones, elevated by geological causes long ago. The direction of the stream was parallel to its trend. On the one side, were the soft Cambro-Silurian shales, geographically higher, geologically lower; on the other (southern) side, the Niagara limestones, beneath which were the soft Medina shales, until these were worn away in part. As the shaly rocks were removed the limestones would be undermined, and therefore we had the NIAGARA ESCARPMENT produced. How far these limestones have receded towards the present face and summit of the slope, is a question yet to be decided. As the waters sunk to a lower level a second escarpment was produced (the one noticed at Port Dalhousie, at the present lake level). Afterwards, the Hudson River shales (with some hard rocks) were pierced, whilst yet there were capping Medina shales, forming the surface of the country between the river and the limestone escarpment.

All this presupposes the continent at a higher level (at least between five

and six hundred feet). Prof. Dana points out that the continent, during at least the Mesozoic, if not the Tertiary times, stood at an altitude equal to this measurement, as shown by the soundings at the mouth of the Hudson river, which extends 80 miles seaward; and Prof. Hillgard has shown that the Mississippi also had nearly an equal elevation above that of the present day.

In the sketch of the topography of Lakes Erie and Huron, we have seen that the whole of the latter lake and the south-western half of the former are excavated mostly out of softer rock; and the north-eastern half of Lake Huron is excavated along the junction of harder and softer rocks similar to Lake Ontario.

The rate at which these upper lakes were excavated would depend on the rate of the excavation of the Dundas valley and its extensions through the limestone, at first by a slow abrasion, and the solution of the carbonate of lime by the carbonic acid held in the water, and afterwards by the undermining of the hard rocks on the removal of the Medina shales.

As to Georgian bay and the North channel, these formed independent valleys. That the North channel is excavated out of the Cambro-Silurian shales, along the junction of Niagara limestones on one hand, and the metamorphic rocks on the other, is apparent at a glance; as we see that the Spanish, Mississagua, Thessalon, and other rivers all point in that direction. It has been noticed that the North channel has the same depth as the deepest outlet; and also that the deeper portions of the northern part of Lake Huron are in that direction. An appropriate coincidence is that the strait between Manitoulin and Cockburn islands should be called Mississagua, which was doubtless the ancient outlet of that river; and False De Tour channel that of the Thessalon river.

Again, Georgian bay is scooped out of the soft rocks between the crystalline rocks on the east and the Niagara limestones on the west along the line of junction, similar to the North channel, or to Lake Ontario.

The Indian peninsula is a perfect counterpart to the Niagara escarpment, and the escarpment submerged beneath Lake Ontario. For here the Niagara limestones tower more than 300 feet above Georgian bay, whilst at the foot, but submerged, there is a precipitous descent of 500 feet below the surface of the lake. The deepest outlet into Lake Huron is only about 300 feet. Whether this is filled with drift deposit or not we cannot say. One thing is certain, that a broad depression in the topography of the country extends all the way from the southern end of Georgian bay, including Simcoe, Balsam, Rice, and a multitude of smaller lakes emptying into the bay of Quinté by the Trent river, to Lake Ontario. A great system of drainage did exist along this line. According to Sir William Logan, this trough is deeply filled with drift. Lake Simcoe is 130 feet above Georgian bay, however, and the height of land in the trough to the east of Lake Simcoe is more than 100 feet higher. It may be said that this trough is bounded by a ridge (known as Oak ridge) which is, according to the levels of the Toronto and Nippissing railway, 893 feet above Lake Ontario, and

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further westward to about the same height. The country gradually rises from Lake Ontario to this ridge, but on passing the summit, it descends nearly 300 feet. This ridge consists of drift to a considerable depth. I have several profiles across it. Yet there are no indications that the rivers, such as the Nottawasaga and others flowing northward into Georgian bay, formerly flowed in the opposite direction, emptying into Lake Ontario by the Humber.

The evidences are not quite clear whether the Georgian bay always emptied (except when the waters were at a much higher level), by the present outlet, or by that just indicated. But from the soundings I am inclined to favor the present route. It may be stated that the writer is assuming too frequently that the present soundings are some criterions of the original depths. This assumption I hope to prove in a subsequent paper, when treating of the drift-deposits, and feel confident that outside of confined channels of comparatively narrow width, or certain bays, that the evidence adduced, with regard to the western end of Lake Erie, holds still nearer to the truth when applied to the more northern waters. If Georgian bay were so filled with drift we ought not to find the deep escarpment situated so close to Indian peninsula.

One more remark is necessary with regard to Georgian bay and the North channel,—that is concerning the deep bays or fiords. All the conditions for the making of fiords as noticed under Lake Superior exist here. Owen sound, one of the largest of those fiords, is situated at the junction of the Niagara and Hudson River Formations, with a buried channel emptying into it, and now occupied by the small Sydenham river. At any rate the fluviatile origin of this rivulet is unquestionable (although Mr. George J. Hinde asserts that it was made by glacial action), after the study that we have made in the Dundas valley. The buried channel of the Sydenham river is more than half a mile wide at the town of the same name.

Some of the indentations in Manitoulin island were probably formed by rivers flowing across the island, but were closed by drift in portions of their course, thus producing the lakelets and bays. That most of these bays are fiords is apparent, as is also proven by the numerous islands north of Manitoulin islands, the whole being a perfect counterpart of Puget sound, or of the fiords of the Scandinavian peninsula.

Owing to the much greater depth, and other obstacles of the present time, it does not seem at all likely that Lake Huron ever emptied by Georgian bay, excepting possibly at the close of the great floods that made the whole region from Huron to Ontario one body of water, even then the present topography would not favor it.

The Outlet of Lake Ontario. The three great questions, involved in the sub-aërial and fluviatile origin of our three Great Lakes, are, where were the outlets of Lake Ontario, Lake Erie and Lake Huron, at sufficient depths to drain their basins. As shown, the outlet of Lake Erie through the Dundas valley is sufficiently deep to empty the two upper lakes. Also, the outlet

described on previous pages points to every condition necessary to indicate its depth as being sufficiently great to empty Lake Huron, although the actual measurement (on the north-east side of the channel) has only reached to 200 feet below the surface of Lake Erie, with a bottom composed of soft shales. There now remains one other question to be answered, but certainly one of no greater moment than the ancient connection between Lakes Erie and Ontario—the outlet of Lake Ontario.

Dr. Newberry, at times a glacialist, finally appears to advocate the glacial excavation of the lakes after their courses had been determined by river action. Various writers for the last twenty years have referred to the deep buried channel near Lake Onondaga, more than 400 feet below its surface, as indicating the former outlet of Lake Ontario by this route, and down the Mohawk to the Hudson river. This course will not answer, as the Geological Survey of Pennsylvania has shown, for at Little Falls, Herkimer county, the Mohawk flows over metamorphic rock. Various fluvialists refer some buried route by the St. Lawrence. This seems scarcely possible, as that great river flows over hard rocks at various points for 200 miles eastward of Lake Ontario, unless the outlet existed somewhere between Kingston in Canada, and Oswego in New York, and continued in a buried course through crystalline rocks (in part) to eastward of Montreal. The north-eastern portion of Lake Ontario is very shallow, and the deepest channel points to the south-eastward extremity of the lake.

At the present time the writer knows nothing positively of the most probable outlet, as that by the Mohawk will not answer. Yet he will predict that its outlet will be found as certainly as the one between Lakes Erie and Ontario, of which there was no clue, or even suggestion until working up the origin of the Dundas valley. One other route presents itself, but as positive proof is not at hand, I will defer theorizing.

The Geological Survey of Pennsylvania has shown that many of the water courses, emptying southward at the present time, formerly emptied to the northward. In New York, we find most of the small lakes of narrow but long dimensions having their axis in a meridional direction. Also, these waters are generally along some stream flowing northward into Lake Ontario even at the present time. Though the bottoms of these lakes are frequently below the sea level, yet in no case, that I am aware of, are they nearly as deep as Lake Ontario. Doubtless these small lakes were former expansions of the rivers running into Lake Ontario in Preglacial times, and owe to ice, simply, the closing of their outlets by drift.

No local land oscillations apparent. I agree with Mr. Carll that there are no indications of local oscillations in the region of our lower great lakes, at least to account for any changes in the drainage systems. It has been a popular idea that the coast of New England, even at the present time, is sinking. If so, any changes must be very slow, for Mr. Henry Mitchell, of the United States Coast Survey, shows (in appendix 8 of report for 1877), that the whole north-eastern coast of the United States has undergone no change of level during the last hundred years.

Depths of the lakes cannot be accounted for by the relatively higher elevations of northern latitudes. In the first place, Lake Ontario has a bottom very much deeper (below the sea), than even the deepest sounding in Lake Superior, or 500 feet below sea-level.

If a sufficient elevation did occur, it would require to be local, or to extend far to the southward. That it was not local appears from the general dip of rocks in which it lies.

However, any continental elevation or subsidence occasioned by the change of the centre of gravity of the earth, such as that by the great accumulation of ice in the polar regions, would be equal to the elevation or subsidence at the pole multiplied by the sine of the latitude. From this we find that if the elevation at the poles were a thousand feet, the difference between the elevation or subsidence of the northern end of Lake Huron and the Dundas valley, would be equal to only about 40 feet. Even were the ice-cap uniform around the poles, it has never been calculated that it was sufficient to cause a polar difference of 3000 feet of level, which at most would effect the relative levels of the northern end of Lake Huron and the southern latitude of Ontario to no greater extent than 120 feet. Again, it is shown by Prof. Whitney, that no ice-cap occupied north-western America, and by the author of "Fire and Frost" (see Q. J. G. S.), that the ice-belt is only known to have surrounded the region of northern Atlantic. The greatest changes of level by the accumulation or removal of ice would thus be occasioned along the north-eastern margin of America in the region of the Appalachian and Laurentian mountains. If the continent continued high during the Ice Age, the coastal ranges would cut-off most of the moisture, and thus greatly lessen the thickness of any *ice sheet* over the region of the great lakes, if it ever did exist. This is exactly the state of the ice in Grinnell land (Lat. 81° N.). Messrs. Fielden and Rance, observed "the paucity of glaciers, and the non-existence of the ice-cap," (Q. J. G. S., No. 135), and state that no glaciers descend to the level of the sea, as on the Greenland coast or Hall basin.

The idea of the lake basins being greatly effected by oscillations must be abandoned, except so far as the whole area was subject to a more or less uniform change acting proportionably on the eastern and central parts of the continent. Even then, the change was far too little to explain the depths of these waters. Another evidence against the irregular changes of the lake region is that, at the close of the Ice Age we have terraces in Canada a thousand feet or more above the sea, and at various levels all the way to the present surfaces of the waters. Terraces or ridges occur at similar heights in our country, Ohio, New York and elsewhere. In a subsequent paper the writer hopes to show the relation existing between these old beaches, terraces and kames, deposited when our three lakes formed one common body of water. That this water had numerous outlets, as the continent was rising, has been pointed out by the Geological Survey of Ohio, to say nothing of the outlets referred to by the Surveys of Pennsylvania and Canada. At only a comparatively few levels did the waters seem to

linger, as the lower lake region was being desiccated, and therefore we do not find continuous shore lines between many of the beaches; Carll explains this by the waters being frequently lowered by *débâcles*, apparently an adequate reason.

Niagara River. That the Niagara river is Postglacial, at least from the Whirlpool to Queenston, is apparent. It is known that the Niagara river formerly left its present course near the Whirlpool and flowed down the valley of St. David, which is now filled with drift. This valley (through the limestone escarpment) is not so great as the present *cañon*. This buried valley of St. David could only have been produced after the closing of the Dundas valley outlet of the Erie basin, for until then the waters flowed at a very much lower level. Therefore, it seems necessary to regard this channel (not of very great magnitude) as an interglacial outlet for Lake Erie.

The geologists of the Western States point to the Forrest bed as a period of high elevation, preceded by the Erie clay (stratified) and succeeded by the yellow stratified clays or loam, corresponding to the Brown Sangeen clay of Canada, which is unconformable to the underlying Erie clays (or Boulder clay in the upper portion of the Dundas valley). So, for the present, we look upon the old course of the Niagara river as the channel excavated during this warm interglacial period.

Hypothetical Glacier Origin of the Lakes. The writer, having purposely left the hypothesis that the lakes were excavated by glaciers until now, will briefly examine what evidence is existing. One cannot do better than give a summary of what Prof. Whitney (in Climatic Changes) says with regard to the erosive power of ice. "Ice *per se* has no erosive power." Glaciers are not frozen to their beds. Ice permeated with water acts as a flexible body and can flow accordingly. In neither the extinct glacier regions of California nor in the shrunken glaciers of the Alps will it be found that ice scoops out channels with vertical sides as water does.

"No change of form can be observed at the former line of ice. Aside from the morainic accumulations, there is nothing to prove the former existence of the glacier, except the smooth, polished or rounded surfaces of the rocks, which have no more to do with the general outline of the cross-section of the valley than the marks of the cabinet-maker's sandpaper have to do with the shape and size of the article of furniture whose face he has gone over with that material."

The most important work of a glacier is the scratching and grooving of surfaces. This may, however, be done by dry rubbing, and therefore isolated scratched stones or patches are no evidence. The underlying rock surfaces may lose their sharpness, owing to contained detritus in the ice, and become rounded. The ground moraine is neither characteristic nor important. There is but little detrital material beneath Alpine glaciers, and this is the result of water more than ice. The only characteristics of ice action are striation and polishing. All floating ice shod with stones frozen in them will scratch surfaces over which they rub. The only gla-

cial lakes that are formed are those where pre-existing valleys have been closed by morainic matter, but the waters will soon reöpen these dams by running over them.

Such are the deductions of the late Director of the Geological Survey of California, a man who has had opportunities for studying the action of glaciers better than most geologists in America. So far, Prof. Whitney's investigations are applicable to our great lakes, though I do not agree with him that some of them occupy geological valleys (unless possibly Lake Superior).

Mr. George. J. Hinde, F. G. S., one of the few geologists who has written from a Canadian standpoint, is an uncompromising glacialist. Because he has seen scratches in the north-eastern end of Lake Ontario, and also others in a similar direction at the western end of the lake, therefore he asserts that Lake Ontario was excavated by a glacier. Dr. Newberry accepts his statement as proof, but considers that a Preglacial valley determined the direction of the continental glacier.

Mr. Hinde also asserts his belief that the buried valley of the Niagara river (by way of St. David's) as also the valleys at Dundas and Owen sound, are of glacier origin. We have proved in this paper incontrovertibly that the Dundas valley is a buried river channel. Also it has been seen that Owen Sound and the St. David's valley are both beds of Preglacial or Interglacial rivers.

Let us analyze the direction of the ice scratches in the neighborhood of the western end of Lake Ontario. I have not seen any (out of very many sets), that is parallel with the axis of either the Dundas valley (except *possibly* one polished surface in the valley), or the axis of the lake, but always at considerable angles. In the region of Kingston, the prevailing scratches are S. 45° W. (Bell) and some others at S. 85° W, neither of which directions are parallel with the axis of the lake. Granted that Mr. Hinde observed scratches that were parallel with the axis of the lake, they of necessity would have been at an angle with the submerged escarpment. If any glacier could have scooped out the basins of Lake Ontario, it left the summit edges of the Niagara escarpment as sharp as possible, and not planed off. Also, if it excavated the deep trough of the lake, it left a summit of soft Medina shales over the harder Hudson River rocks of the submerged escarpment, beneath which are Utica shales. From Dundas to the Georgian bay the face of the escarpment (Niagara) is less abrupt, but even here, there has not been left more than 50 feet of drift at its foot, and this mostly, if not altogether, stratified (excepting in channels now buried).

The observations of Prof. Prof. H. Y. Hind, on the coast of Labrador, are here interesting. He has shown that *pan ice*, at the present time, is polishing the sides of cliffs, and has been continuing its action whilst the coast has been rising several hundred feet. Even under the ledges of overhanging rocks the action is now going on (a phenomenon which, if in the lake region, would be attributed to glaciers). Also, he has seen boulder clay being formed at the present time by the action of *pan ice* (frozen sea-

water). This, with a thickness of eight or ten feet gets piled up by the action of waves and wind, and consequently in the bays of the coast of Labrador it polishes rock bottoms to a depth of fifteen feet or more, below the surface of the water, and grinds off rough surfaces. I have frequently seen, myself, in northern regions, high boulders transported by the ice to which they were frozen in the margin of small lakes.

From what has been written, it seems to the writer that the glacial origin of Lake Ontario does not rest on a single basis further than that ice scratchings (producible by either glaciers or icebergs, neither of which need be great erosive agents) are seen at various places about Lake Ontario, both above and below the water-level. The remarks applied to Lake Ontario hold good for the other lakes. The description of their topography strengthens the proofs that their origin cannot be accounted for by glaciers, because we find the islands at the western end of Lake Erie, or northern end of Lake Huron, polished and striated.

Before closing, permit me to thank those railway companies which have kindly furnished me with many levels. But in doing this, I may state that it is my purpose to make further requests and hope to do for Ontario, what the Pennsylvania Survey has done, in collecting all levels that bear on the topography of my native Province, in order to make a more complete study of the Preglacial drainage of the great lake region.

Geological Section at St. Mary's, Elk County, Pennsylvania. By Charles A. Ashburner, M. S.

(*Read before the American Philosophical Society, March* 18, 1881.)

Introduction. Probably no locality within the Bituminous Coal Fields of Pennsylvania has had so many and such conflicting reports published on its coal geology as the counties of McKean and Elk. Had these reports been made with the desire of merely collecting facts, and of showing their true correlation, we would no doubt long before now have reached the truth in regard to the systematic geology of the coal measures; unfortunately for science, for the geologist and the capitalist, most of the individual investigators have been biassed and prejudiced in their studies, by a natural desire to find favorable facts, from which to deduce conclusions enhancing property values. In many cases true facts have been presented, but as a rule they have not been sufficiently numerous from which to draw conclusions of a correctness beyond question or doubt.

As we look back over the varied history of this region during the past twenty years, examine the reports which have been made, both privately and publicly, note the mineral development of the region, consider the results attained, estimate the profit and loss in money value, and count the benefits accruing to the land owner, the county and Commonwealth, the picture presented is unsatisfactory. The steady, permanent develop-

ment of the coal fields has been misdirected, and consequently retarded. Investments have too often met with disappointment, followed by failures.

A geologist cannot manufacture good coal beds or purify poor ones; and he steps beyond his professional bounds as a practical geologist when he attempts aught else than the discovery of facts and their true economical interpretation.

If there are any advantages to property holders to be derived from too favorable and rose-colored reports, they are certainly only immediate and are insignificant in comparison with the more permanent ones resulting from true, unbiassed and less favorable reports.

I have prefaced my paper with these remarks, because the results of my examinations in the counties mentioned have two direct and important but quite independent bearings; one is purely commercial in its aspects, as it interests and affects the land owner and coal operator; the other belongs to the province of pure geology concerning only the geological investigator and student.

It is my present purpose to merely describe a new interpretation which I have made of the stratification in the vicinity of St. Mary's, Elk County, and to indicate its bearing upon the systematic geology of other portions of the district.

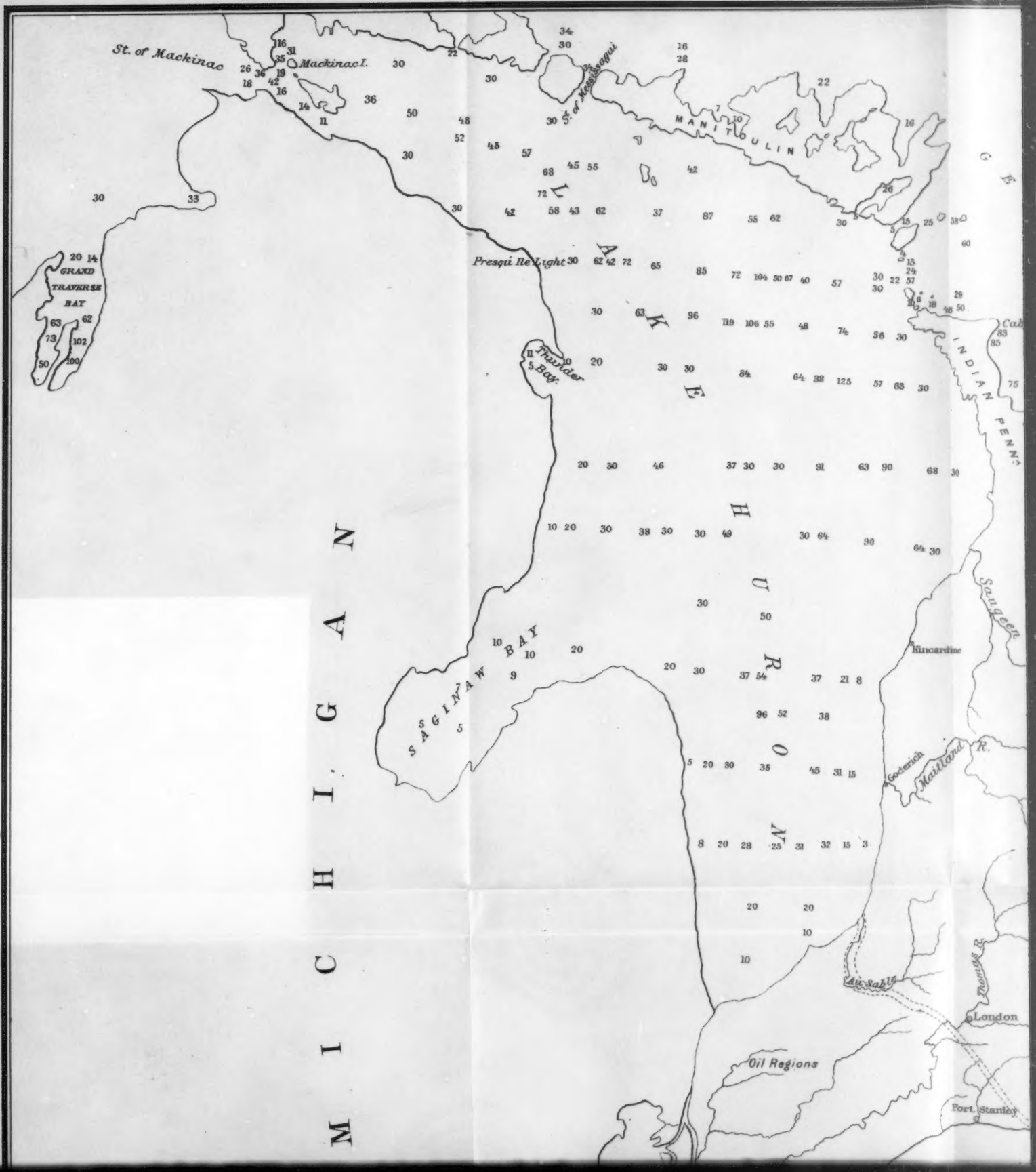
Statement.—The detail geology of McKean has already been published in report R of the Geological Survey; that of Elk will be found in connection with the geology of Cameron and Forest in the forthcoming report RR.

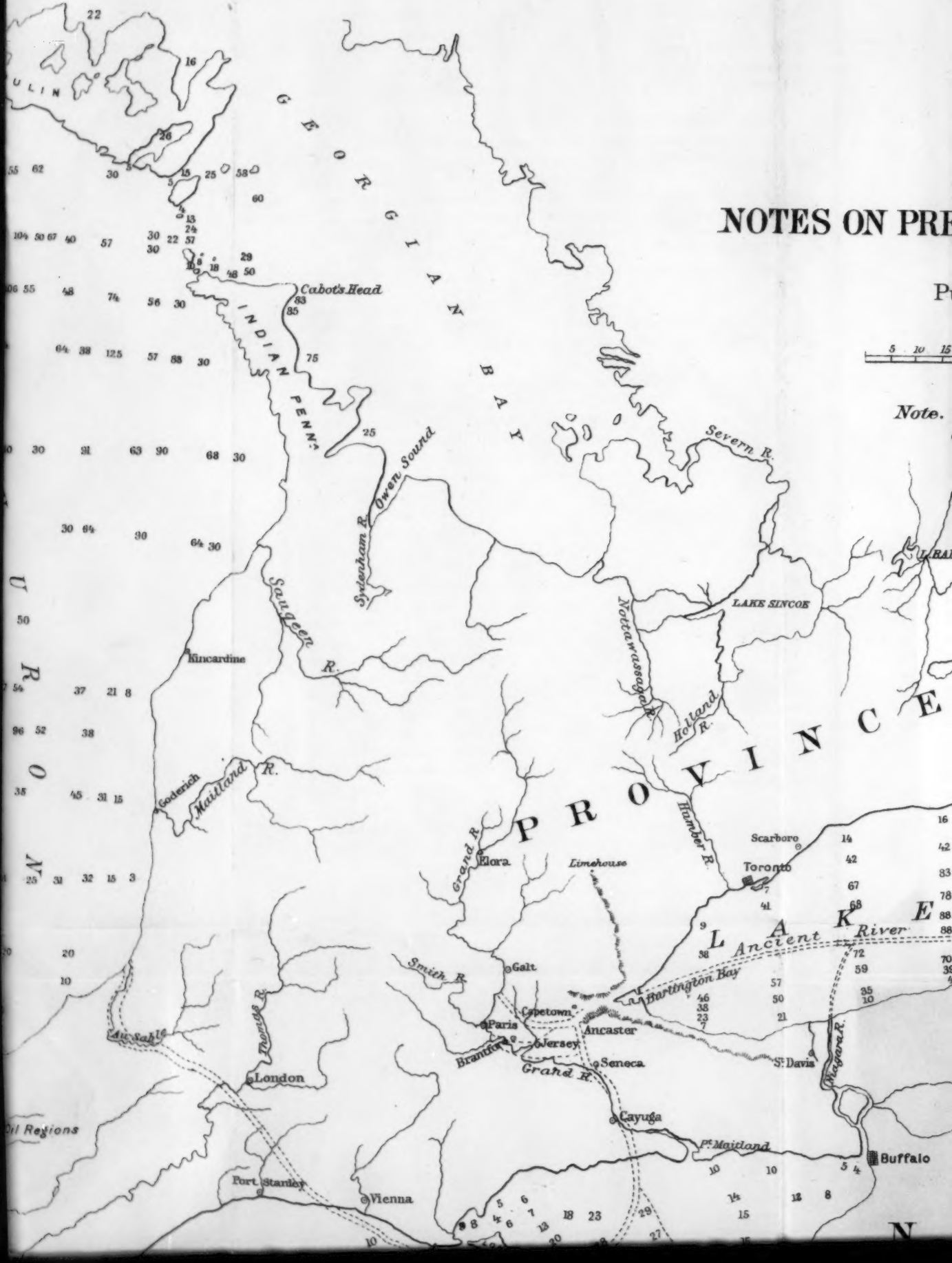
The local geologists of Elk County generally consider the coal measures in the vicinity of St. Mary's to be low in the series; whereas I make them to include the representatives of the Lower Freeport, Kittaning, Clarion and Mercer (or Alton) coal groups.

I fully realize the fact that I am making a statement which is directly opposed to the general views held in regard to the nomenclature of the St. Mary's coal beds. But the most important and difficult problem which I have had to deal with, has been the identification of the coal rocks; and the conclusions which are now advanced have only been reached after a careful detail study of the coal basins of McKean, Cameron, Elk and Forest counties. A great many observations have been made in adjoining counties in order to confirm the work, and connect it with that done by other survey assistants in adjoining fields.

The fact that a rock section contains the representatives of certain well known and established groups, does not necessarily imply that each group has a well defined representation of the individual beds which characterize it at the place of its best development. The special features which have determined the naming of the sub-groups of the coal measures, at their typical locality, may be wanting at many places where the occurrence of the group itself can alone be determined by a comparative study of the entire formation.

From the fact of the St. Mary's section containing the rocks of four of the principal groups of the Lower Productive coal measures in the State,


St. of Mackinac
Mackinac I.
St. of Mississagui
MANITOULIN
Presqu Ile Light
GRAND TRAVERSE BAY
Thunder Bay
LAKE HURON
MICHIGAN
SAGINAW BAY
Kincardine
Saugeen
Goderich
Maidland R.
Au Sable
Thames R.
London
Oil Regions
Port Stanley
INDIAN PENNA


NOTES ON PRE
Note.
GEORGIAN BAY
INDIAN PENN.
Cabot's Head
Owen Sound
Sydenham R.
Saugeen R.
Kincardine
Goderich
Maitland R.
Severn R.
LAKE SIMCOE
Nottawasaga R.
Holland R.
PROVINCE
Scarboro
Toronto
Elora
Grand R.
Limehouse
Hamber R.
Ancient River
Smith R.
Galt
Burlington Bay
Capetown
Paris
Ancaster
Brantford
Jersey
Seneca
Grand R.
St. Davis
Niagara R.
Thames R.
London
Au Sable
Cayuga
Pt. Maitland
Buffalo
Port Stanley
Vienna
Oil Regions

SECOND GEOLOGICAL SURVEY
OF PENNSYLVANIA
J.P. LESLEY, STATE GEOLOGIST.

MAP

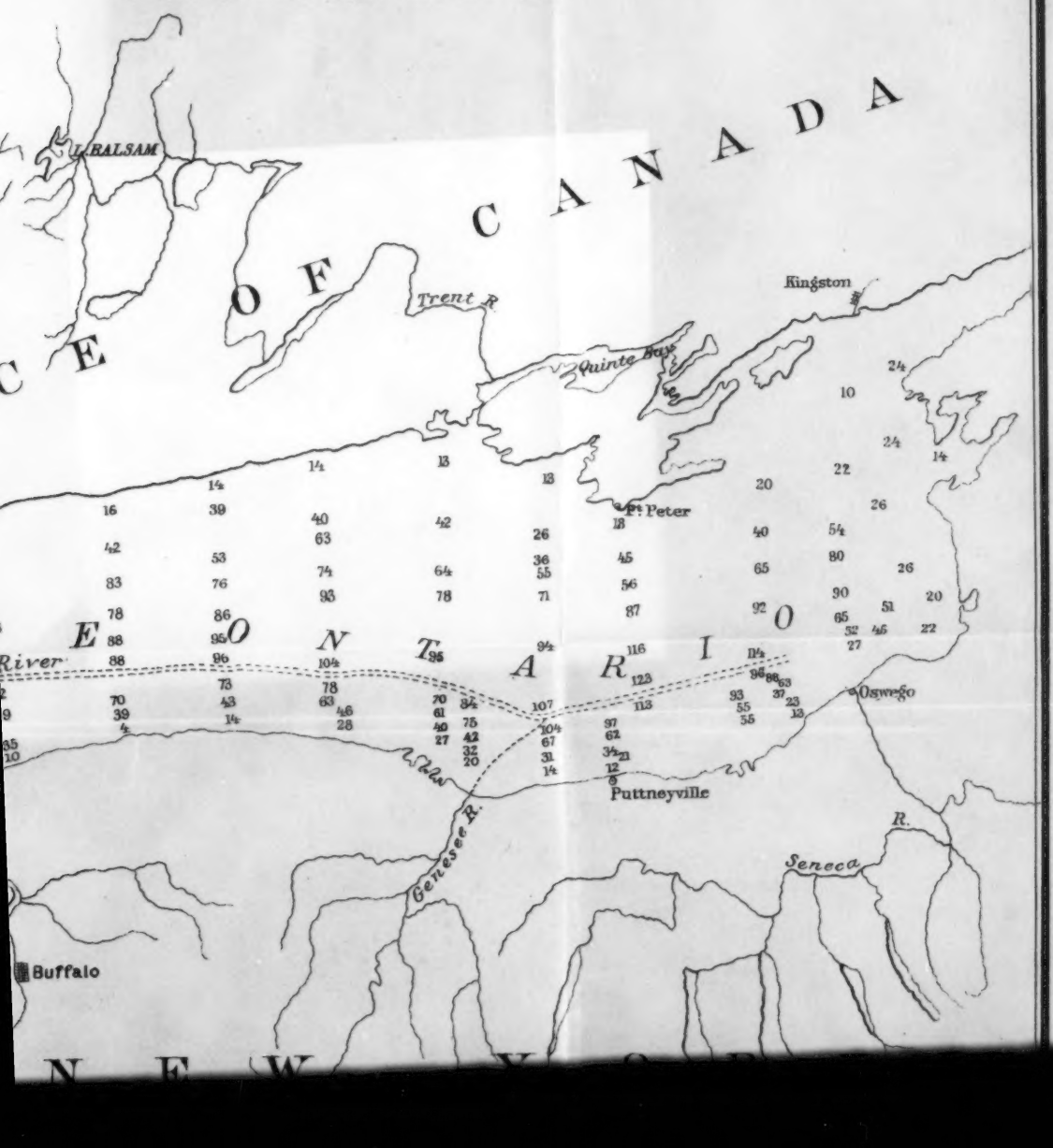
ACCOMPANING

N PREGLACIAL OUTLET OF LAKE ERIE &c.

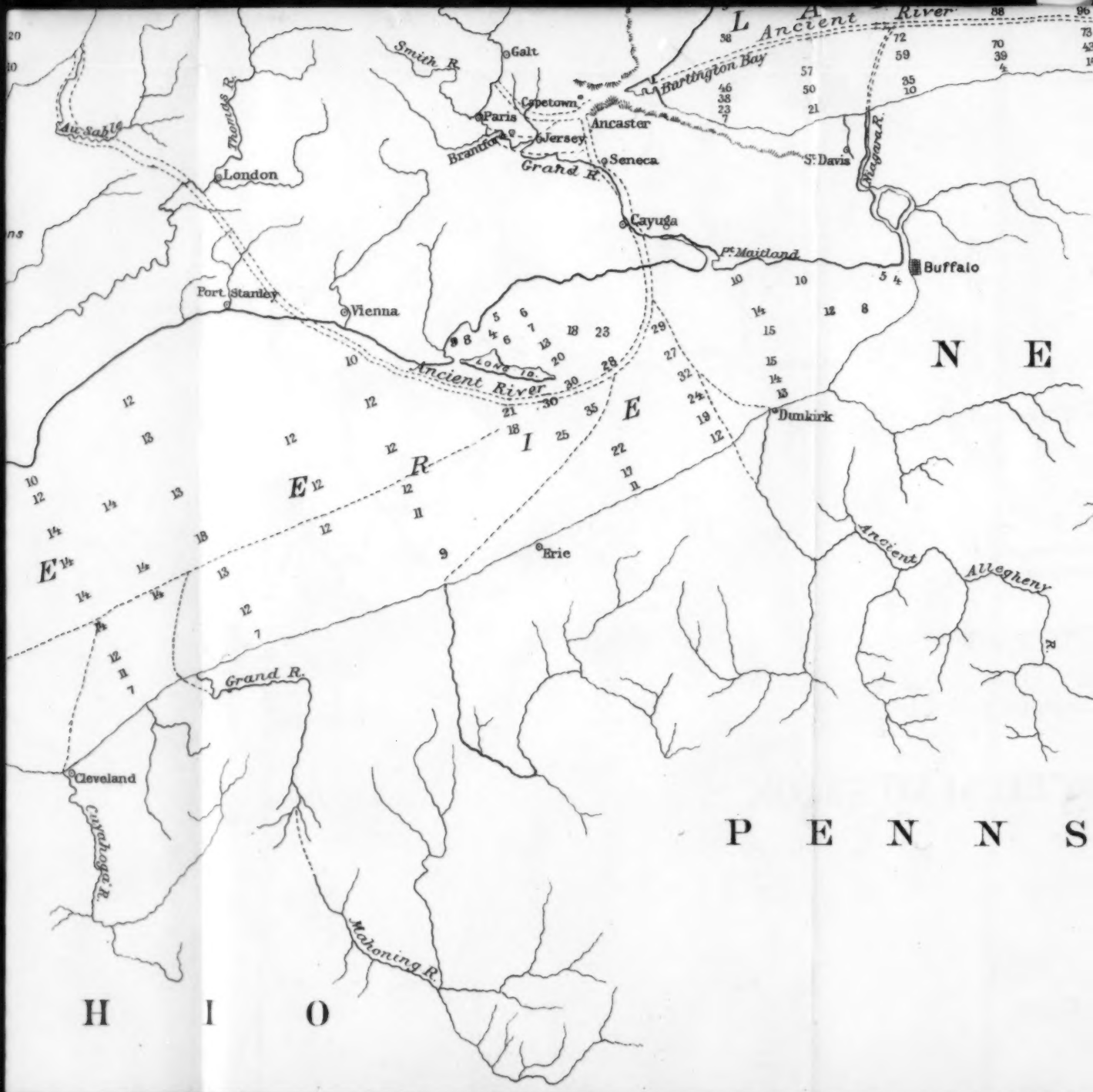
Published in Appendix to Report Q4.
By Prof J.W. Spencer

Scale
5 10 15 20 25 50 75 100 miles.

Note. The figures in the lakes give the depth of water in fathoms of six feet each.



LANE S. HART STATE PRINTER


L A
Ancient River
Smith R.
Galt
Burlington Bay
Capetown
Paris
Ancaster
Brantford
Jersey
Seneca
Grand R.
St. Davis
Niagara R.
Au Sable
Thames R.
London
Cayuga
Ft. Maitland
Buffalo
Port Stanley
Vienna
Long Pt.
Ancient River
Dunkirk
N E
E R I E
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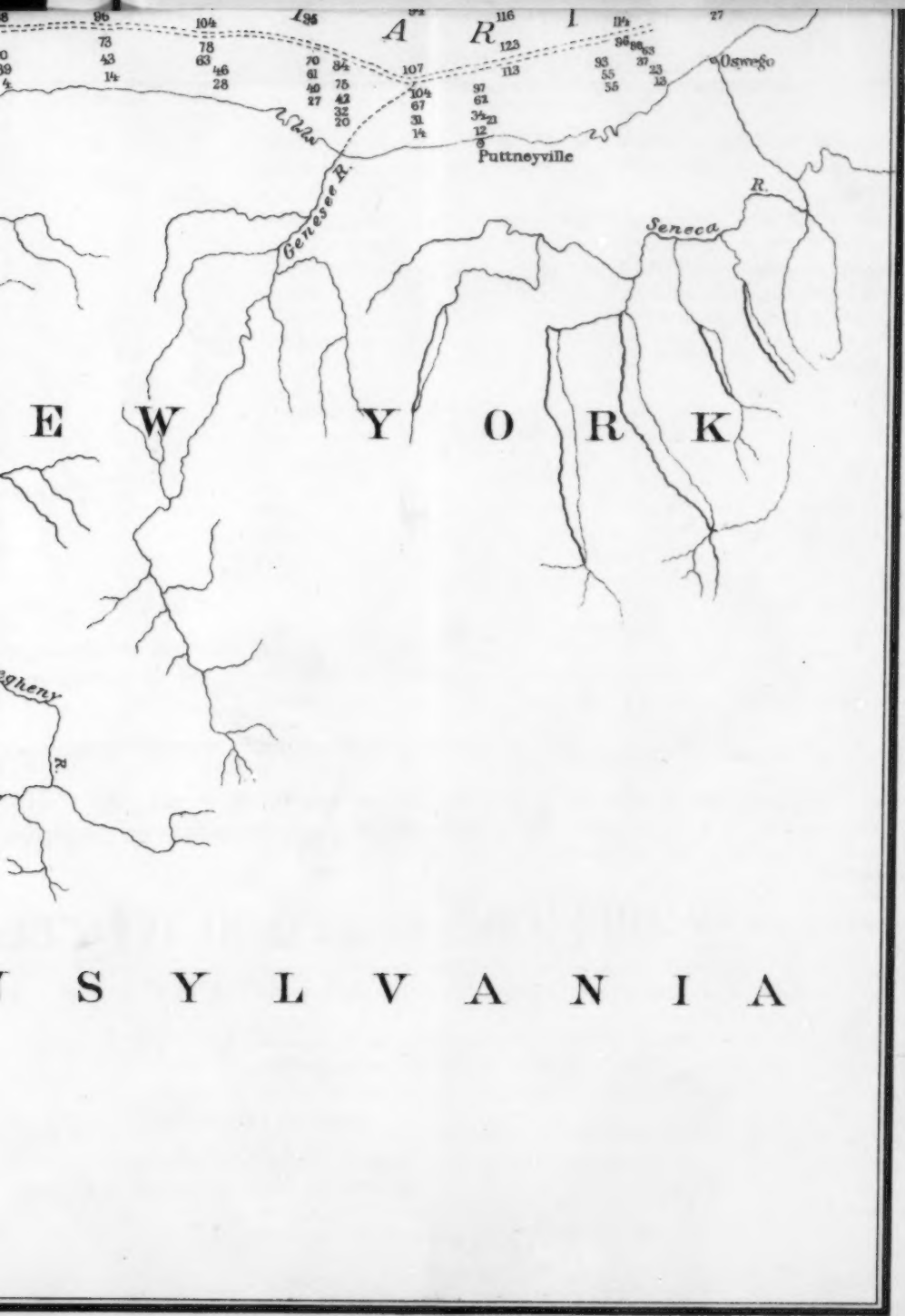
Grand R.
Cleveland
Cuyahoga R.
Mahoning R.
P E N N S
H I O



JULIUS BIEN PHOTO. LITH.

the natural inference would be that a number of valuable workable beds should be found here, out of the eight beds which these groups generally embrace, and which have proved so productive in other portions of Pennsylvania. The fact is, however, that at St. Mary's only one coal bed has as yet been found* of sufficient purity and thickness† to be profitably mined *over any considerable area.* This bed is the Dagus or Lower Kittanning coal bed.

But besides this bed the St. Mary's section contains representatives of the Upper and Middle Kittanning, the Clarion and Mercer coal beds; and the ground at the Patton Hill near the west mine of the St. Mary's Coal Company is high enough to contain a very small area of the Freeport Lower coal, although it has not been discovered.

The following is a general section of the coal measures in the vicinity of St. Mary's, compiled from facts obtained within a radius of one and a half miles of the Philadelphia and Erie railroad station. For the sake of completeness I have added to this section the record of the drill hole of the St. Mary's Oil Company, making in all nearly a half mile of vertical thickness of rocks whose character is actually known:

Elk County Section; at St. Mary's.

1.	Gray sandstone, shale and slate	67
2.	Coal, *Kittanning Upper*	3′
3.	Sandy shale and slate	33′
4.	Coal, *Kittanning Middle*	1′ 6″
5.	Sandstone and shale	55′
6.	Coal, *Dagus, Kittanning Lower*	3′
7.	Fireclay‡	3′
8.	Shale	17′
9.	Coal	1′ 4″
10.	Sandstone and shale	10′
11.	Limestone and shale, *Clermont, Ferriferous*	10′
12.	Shale	13′
13.	Coal	5″
14.	Shale	16′
15.	Coal, *Clermont, Clarion*	2′
16.	Sandstone and shale, JOHNSON RUN S. S.	32′
17.	Coal, *Alton Upper*	2′ 7″
18.	Shale	18′

*The Clermont or Clarion bed has been worked to a limited extent on the Monastery lands east of Silver creek, about three-quarters of a mile northwest of the St. Mary's railroad station.

†The degree of purity and extent of thickness necessary to constitute a workable, marketable coal bed, are purely arbitrary, and their values are dependent upon commercial questions.

‡A fireclay bed invariably forms the floor of all our bituminous coal seams. They have not been noted in the section except where their thickness has been determined; in most cases they have been included in the rock interval beneath each coal bed.

19.	Coal, *Alton Lower*		3′
20.	Sandstone, KINZNA CREEK S. S.		45′
21.	Shale and Coal		10′
22.	Sandstone and conglomerate, OLEAN CONGLOMERATE		50′
23.	Slate, sometimes containing a coal bed 2′ thick		10′
	Total		406′
24.	Grit, clay and gravel (top of St. Mary's drill hole)	18′ to	18′
25.	Sand	18′ "	50′
26.	Interval	45′ "	95′
27.	Sand	25′ "	120′
28.	Interval	140′ "	260′
29.	Sand	16′ "	276′
30.	Interval	124′ "	400′
31.	Sand	20′ "	420′
32.	Interval	205′ "	625′
33.	Red shale, sandstone and slate	335′ "	960′
34.	Interval	12′ "	972′
35.	Sand	49′ "	1021′
36.	Interval	369′ "	1390′
37.	Red sandstone	25′ "	1415′
38.	Interval	35′ "	1450′
39.	Reddish rock	5′± "	1455′
40.	Interval	215′ "	1670′
41.	Sand	44′ "	1714′
42.	Gray and black slate, containing shells and streaks of red	286′ "	2000′
43.	Fine bluish-white sand	10′ "	2010′

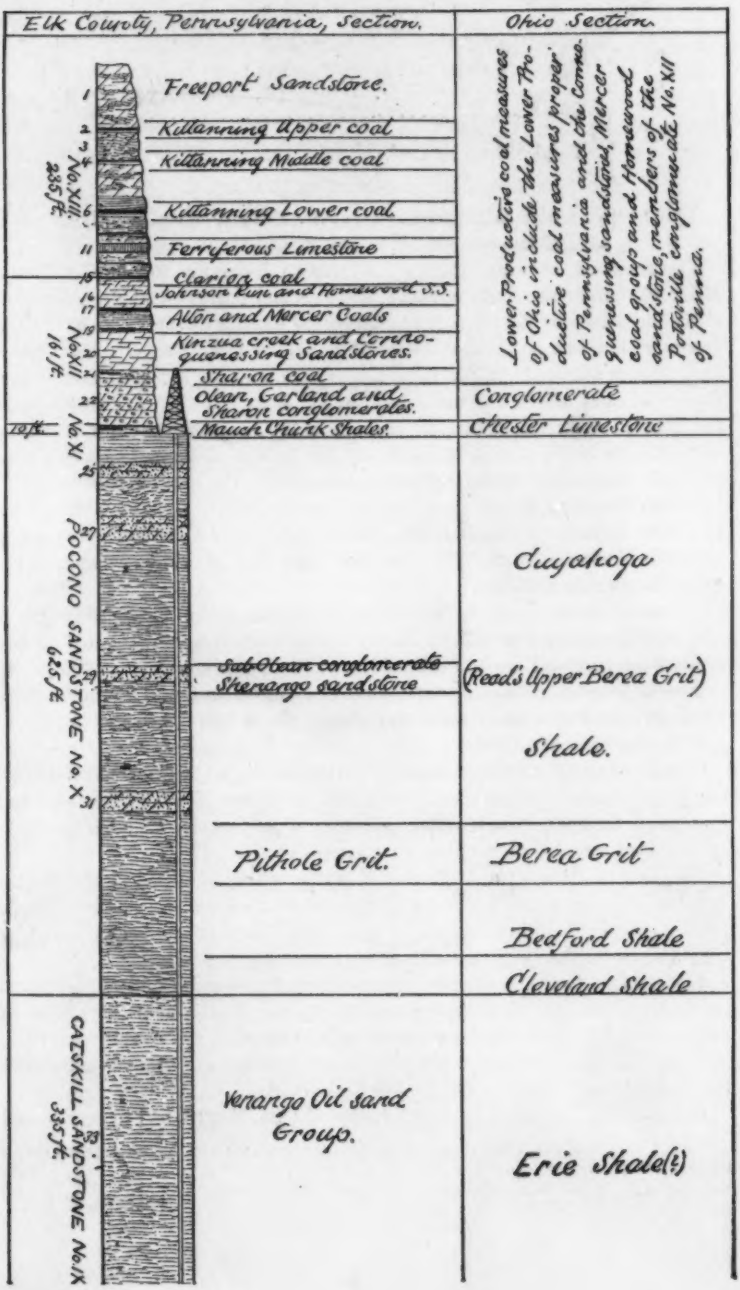
The record of the well is given just as it was reported by Mr. W. W. Ames, who had copied it from the driller's book. The undescribed intervals contained generally gray slate.

A small *gas vein* was struck at a depth of 550 feet; at 972 feet a very much larger one was found. At a depth of 450 feet and 1020 feet salt water was encountered. The geological horizon of the *Bradford Oil sand* is at least 250 feet below the bottom of the St. Mary's test well.

The section may be grouped into formations as follows:

CARBONIFEROUS AGE.

XIII.	Lower productive Coal Measures (1 to 15 incl.)	235′
XII.	Pottsville conglomerate (16 to 22 incl.)	161′
XI.	Mauch Chunk shale (23)	10′
X.	Pocono shales and sandstones (24 to 32 incl.)	625′
	Total	1031′


Elk County, Pennsylvania, Section.
Ohio Section.
Freeport Sandstone.
Kittanning Upper coal
Kittanning Middle coal
Kittanning Lower coal.
Ferriferous Limestone
Clarion coal
Johnson Run and Homewood S.S.
Allon and Mercer Coals
Kinzua creek and Coreto-quenessing Sandstones.
Sharon coal
Olean, Garland and Sharon conglomerates.
Mauch Chunk Shales.
No. XIII. 235 ft.
No. XII 161 ft.
No. XI 10 ft.
POCONO SANDSTONE No. X 625 ft.
Sub-Olean conglomerate
Shenango sandstone
Pithole Grit.
CATSKILL SANDSTONE No. IX 335 ft.
Venango Oil sand Group.
Lower Productive coal measures of Ohio include the Lower Productive coal measures proper of Pennsylvania and the Connoquenessing sandstone, Mercer coal group and Homewood sandstone, members of the Pottsville conglomerate. No. XII of Penna.
Conglomerate
Chester Limestone
Cuyahoga
(Read's Upper Berea Grit)
Shale.
Berea Grit
Bedford Shale
Cleveland Shale
Erie Shale(?)

DEVONIAN AGE.*

IX.	Catskill sandstone and shale (33).....	335′
VIII.	Chemung shale and sandstone (34 to 43 incl.)...	1050′+
	Total.....	1385′
	Total of known rocks.....	2416′

Lower Productive Coal Measures.

This group, which is 235 feet thick at St. Mary's, contains only one coal bed which has proved productive to any great extent.

The rocks of interval No. 1 of the section form the top of the Patton Hill and include the FREEPORT SANDSTONE and possibly the *Freeport limestone* and *Freeport Lower coal bed*, although neither of the latter have been discovered. Ten miles south-west of St. Mary's the *Freeport limestone* is only 40 feet above the Kittanning Upper coal, and the Freeport Lower coal is only 50 feet above the same bed; at St. Mary's the top of the hill is 67 feet above the latter. The total absence of the Freeport coal and limestone here, argues either a disappearance of the beds to the north-east or a considerable thickening of the Freeport sandstone in the same direction.

The *Kittanning Upper coal* (stratum 2) is reported to have been found in a well dug near Patton's house. This is the only place in the township where it has been found. The bed is said to be 3 feet thick, but has never been thoroughly tested.

The *Johnstown cement bed* which occurs between the Kittanning Upper and Middle coals has not been found; it is, however, well defined in the sections of Fox and Horton townships, to the south-west.

The *Kittanninny's Middle coal* (stratum 4), has been found on the Cascade Mining Company's tract (Kaul and Hall). It is only 18 inches thick and not workable.

The *Dagus or Kittanning Lower bed* (stratum 6), is the principal and most important coal. It has been worked in the mines of the St. Mary's Coal Company, Cascade mines, Tanne.dale mines, Keystone mines and has been opened and tested on a number of other properties.

This bed is without doubt the same as that which is mined by the Northwestern Mining and Exchange Company near Centerville, and which is locally called "C" bed and the "Gas Vein," which has been opened by Genl. Kane on the Roberts lot in Jones township.

Objections.—Local geologists have always considered the St. Mary's bed to be very much inferior to these two latter seams. This conclusion, although unquestionably false, has been based upon three very significant facts:

First. The St. Mary's bed is found at a very much lower level than either the "Gas Vein" or the "C" bed at Centerville.

Second. No limestone is found under the St. Mary's bed to correspond

*The Devonian Age here is made to include the Catskill formation, in order to agree with the accepted division of the Palæozoic Period in the Penna. Survey reports. I believe, however, that the Catskill rocks are of Carboniferous age.

with that formed at Genl. Kane's quarry 40 feet under the "gas vein" or 40 feet below the "C" bed on Toby creek.

Third. The St. Mary's bed is rustier in appearance and does not produce as rich a coal as either the "gas vein" or "C" bed, at the same time the floor and roof of the three beds differ materially in the three localities.

Although these are pointed and pertinent objections against the indentity of the three beds, I have not found any facts to sustain them; to the contrary, the weight of evidence, when carefully considered, is directly in support of the conclusion, which after four years of field work I have no hesitancy in asserting, that the coal bed mined by the St. Mary's Coal Company, by the North-Western Mining and Exchange Company and which has been opened on the Roberts lot above the limestone, is in every case the representative of the Lower Kittanning coal bed.

Demonstration.—It is impossible to give as many facts to prove my position in this paper as I shall present in the published volume of the survey, but I think I can answer these objections in a way satisfactory both to myself and reader.

1. The following elevations above tide will show the relative heights of the bed in the three localities:

At St. Mary's it is	1775 feet.
*Near Centerville it is	1835 " †
On the Roberts lot it is	1975 "

These three places are in three different and quite independent coal basins, and it would be unnatural that there should be any fixed or definite relationship existing between their heights. The Roberts lot is in the Fifth Bituminous coal basin and this is separated by a high, broad anticlinal, running in a north-east and north-west direction, east of Ridgway, from the Fourth Basin in which St. Mary's and Centerville are located. The mines at these two latter places are *in different sub-divisions of one main synclinal.*

I think every one acquainted with the facts in the vicinity of St. Mary's and Centerville, will recognize the fact that between the east and west mines of the St. Mary's Coal Company there is a synclinal axis having a north-east and south-west direction, and that the head waters of Toby creek near the mine marks nearly the position of another synclinal axis; that these two axes are not continuations of one another would be evident to any one studying the facts carefully on the ground.

I am aware that this latter conclusion will be vigorously opposed, but I believe it cannot be absolutely denied until more *facts* are brought forward to oppose it, than I have to confirm it.

2. In regard to the *limestones* it seems to be quite certain that the limestones and shales composing an interval of 20 feet, 40 feet below the "gas

* Head of Toby creek. The same coal is 1922 feet, ¼ mile north of the Centerville store.

† On a profile just received from Mr. Oliver W. Barnes, the approximate elevation of the coal bed at the mine of the North-Western Mining and Exchange Company is stated to be 1779 feet. The elevation here given (1835') is based upon the elevation of the road at Centerville, in front of McCauley's store, which, according to Dr. C. R. Earley, is 1963 feet above tide.

vein" on the Roberts lot; the limestone which is 6 feet thick and 40 feet below the "C" bed at Centerville, and the limestone bands and shales 10 feet thick exposed in a railroad cutting one mile east of the coal shutes of the St. Mary's Coal Company, and 31 feet below the St. Mary's bed, are all representations of the *Ferriferous limestone.*

This conclusion is based upon a comparative study of all the individual members of the rock sections in the three localities. On account of the bad exposures in the Johnson run basin in the vicinity of the Roberts lot and along Toby creek, and on account of the limestone in the two places lying low in the valleys, it has always been difficult to determine the rock thicknesses below the limestone. This fact has resulted in each case, of placing the limestone too high in the measures, and consequently an error in the identification.

It is generally believed that no limestone occurs at St. Mary's. On careful search an outcrop of the bed may be found on a hill north-west of the railroad station. I have been told upon good authority that pieces of stone have been gathered here which have been burned into lime. This limestone is the same bed which is shown in Rogers' section (Vol. II, p. 522, Final Report First Survey).

It has been reported that the limestone which was located by the assistants of the First Survey was planted by persons having coal interests, with the view of deception. Neither Prof. Rogers nor his assistants were deceived; the limestone which is placed in the section already noticed occupies exactly the same relative position as that in the accompanying section.

The *Ferriferous limestone* has a variable character throughout Western Pennsylvania, so that a difference in the quality and thickness of the beds in the three localities named do not argue against their identity.

3. The character of the *Dagus* or *Kittanning Lower bed*, together with its flooring and roofing strata, are found to vary considerably within the immediate vicinity of St. Mary's, where its identity may be determined by the engineer's level alone.

The following analyses, made by Mr. A. S. McCreath, show marked variations in the chemical constitution of the coal:

	a.	*b.*	*c.*	*d.*
Water	.990	1.190	1.050	.990
Volatile matter	38.355	33.990	39.295	40.585
Fixed carbon	52.826	50.990	48.001	49.416
Sulphur	2.044	3.118	3.324	3.369
Ash	5.785	10.710	8.330	5.640
	100.000	100.000	100.000	100.000
Color of ash	reddish gray.	lilac.	pink.	pink.
Coke per cent	60.655	64.820	59.655	58 425
Fuel ratio	1:1.37	1:1.50	1:1.22	1:1.22

a. Tannerdale mine, worked by St. Mary's Coal Company, two miles

north-east of St. Mary's. Average thickness of coal 2 feet 6 inches. Coal, dull black, more or less coated with iron oxide; partings of pyrites in very minute crystals partly decomposed.

b. East mine, St. Mary's Coal Company. Average thickness of coal 3 feet 2 inches. Coal, dull black, brittle, iridescent, numerous partings of pyrites and slaty coal.

c. West mine, St. Mary's Coal Company. Average thickness of coal 3 feet. Coal, dull black, more or less stained with iron oxide, rather friable and contains numerous partings of pyrites and slaty coal.

d. Cascade mine, Kaul and Hall. Average thickness of coal 3′ 8″.

Coal, deep black, lustrous and coated with silt; contains considerable pyrites, which is partially decomposed.

For the sake of comparison I have added the analyses of the Roberts lot coal and the coal of the North-Western Mining and Exchange Company at Centerville, and of the *Clermont, Clarion* bed on the Monastery lands:

	e.	*f.*	*g.*
Water	2.460	1.080	.870
Volatile matter	37.990	38.455	37.890
Fixed carbon	52.816	53.190	52.657
Sulphur	.814	1.975	.838
Ash	5.920	5.300	7.745
	100.000	100.000	100.000
Color of ash	yellow.	gray pink tint.	cream.
Coke per cent	59.550	60.465	61.240
Fuel ratio	1 : 1.39	1 : 1.38	1 : 1.39

e. Hoyt opening on "gas vein" Roberts' lot, Jones township. Coal has a dull black luster; cannelly structure; laminæ indistinct; fracture generally irregular, but with a tendency to a cubical.

f. "C mine" North-Western Mining and Exchange Company. Average thickness of coal 3 feet 6 inches. Coal, deep black, lustrous, brittle; shows numerous thin partings of pyrites in minute crystals, partially decomposed.

g. Silver creek mine on Clermont bed, Monastery lands, D. Eldridge operator. Average thickness of coal 2 feet. Coal, deep black, lustrous, brittle, no crystals of pyrites observed. By a comparison of these analyses it will be found that greater differences exist in the composition of the bed in the immediate vicinity of St. Mary's, than between the coal at Tannerdale, Centerville and Roberts' lot, or between the coal from the bed at any one of these three places, and that taken from the Silver creek mine on the Monastery lands.

There is no characteristic *belonging* to the Kittaning Lower coal bed, which may serve as a means for its identification. Where the greatest differences in the composition of the bed exist, as at St. Mary's, the coal can be easily traced and located in the series, by observations made on the

topography; where the composition of the bed is most similar, as at Tannerdale, Roberts' lot and St. Mary's, it requires all the skill and judgment of a trained geologist to determine their geological relationship.

In the east mine of St. Mary's Coal Company the roof is found to change suddenly from a black slate to a hard, massive sandstone. The same thing is reported to have occurred in the now abandoned Keystone mine.

Conclusion.—In view of these facts as regards the variation of the composition of the Dagus or Kittanning Lower coal bed and the changes which are liable to occur in the associated strata within a small area, similar differences at localities so far removed from one another as St. Mary's, Centerville and Roberts' lot, can certainly have but little weight in determining the relative position of the beds.

The best and most reliable means of ascertaining the connection existing between distant rock sections is, by making *a comparative study of sections in their entirety.* A marked similarity will oftentimes be found to exist between the general structure of each section, even where no persistency of character is found to exist between the minor features.

Clermont Group.—The *Clermont** or *Ferriferous limestone* has a distinct and well recognized representative in the vicinity of St. Mary's. The horizon of the limestone is 30 feet above the *Clermont* or *Clarion* coal bed. As has been said, pieces of the stone were found along its outcropping level on the hill north-west of the town.

In a railroad cutting two miles north-east of St. Mary's station, and extending from mile-post 130 to 130+500 feet, is found exposed the representative of the Ferriferous limestone. It consists of gray and black shale and slate containing bands a few inches thick of limestone and lime balls, heavily charged with iron. No limestone has ever been found in the Fourth Basin north-east of St. Mary's.

The *Clermont* or *Clarion coal bed* (stratum 15), marks the top of the Carboniferous or POTTSVILLE CONGLOMERATE, No. XII. This is the position usually occupied by the Brookville coal bed, but I failed to recognize its representative any where within my district of four counties. The best illustrations and discussion of the variations of the Clarion and Brookville coal beds and of the underlying Homewood or Kinzua creek sandstone may be found in the Clarion county report by Dr. H. Martyn Chance.

Alton Group.—The position, extent of area and character of the Clermont and Alton group coals is a matter of considerable importance to the coal interests centered about St. Mary's. No geological report can settle the question in a practical way. That the coal beds should exist, *if the strata were perfectly regular*, I can positively assert; that they do not exist at every point, has been practically proven. The strata are liable to change, and it must be left to explorations of the drift, the drill-hole and the shaft, to test practically the economical value of these coal beds.

* *Clermont* is a local geographical name which I gave to this limestone in McKean and Elk counties, its use was only adopted provisionally until its identity with the *Ferriferous limestone* of Western Pennsylvania should have been placed beyond a doubt.

The irregularities which are so characteristic of the Alton group coals in McKean county* belong not only to the Alton coals, but also to the Clermont coal at St. Mary's. Although very little encouragement can be extended the coal operator or land owner as to the value of these beds, it would be presumptuous for the geologist to condemn the territory which by a surface instrumental survey should be found to be high enough to contain these coal seams. The area under which the coal beds *might be found* is very great.

On the Monastery lands, on the east side of Silver creek, the Clermont bed has been extensively worked and has produced a good quality of coal. The coal has been explored for on the St. Mary's Coal Company's tract, but has never been found.

The Alton beds (strata Nos. 17 and 19), have been found on the Monastery lands, on the Keystone and Tannerdale tracts. The interval between the two beds varies from 14 to 23 feet. Each bed is generally composed of two distinct benches of coal, with a stratum of slate or clay between them.

The *Alton* group, which represents the same series of strata as the *Mercer* coal group, sometimes contains three coal beds, as in central McKean, but as a rule it rarely embraces more than two coal beds, as is found to be the case generally throughout Elk.

Resembling in many of its features the Mercer group of Lawrence and Mercer counties, the Alton group differs essentially from the Mercer in containing no beds to represent the Mercer limestones; for no calcareous strata have been seen in it, in McKean, Cameron, Elk or Forest counties.

The shales and clays between the Alton coals frequently contain nodules of iron carbonate ore. The iron is, however, never regularly stratified. These beds represent the Mercer iron shales along the Pennsylvania-Ohio line.

No. XII.—The Pottsville or Carboniferous conglomerate (Millstone grit of the English geologists), does not consist of one solid bed of conglomerate, but is composed of a series of rocks made up of conglomerates, sandstones, shales, slates, fireclays and coal beds, divided as follows:

Johnson run and Homewood sandstone	32′
Alton and Mercer coal groups	24′
Kinzua creek and Connoquenessing sandstones	45′
Marshburg Upper and Sharon coal interval	10′
Olean, Garland and Sharon conglomerates, Second mountain sand and Ohio conglomerate	50′
Total	161′

The first name given for each subdivision is that which was provisionally adopted in McKean county, the latter names are those which are better known along the Ohio-Pennsylvania State line.

The individual members of the Pottsville conglomerate have been fully described in the Survey reports to which the reader is referred.

* Geological Survey, Report R, page 53.

PROC. AMER. PHILOS. SOC. XIX. 108. 2R. PRINTED MAY 3, 1881.

The name *Lower Productive coal measures*, still in use for the sake of convenience, is a purely local and relative term, without classical value. When first applied by the First Geological Survey of Pennsylvania, it was intended to include the workable productive coal beds of Western Pennsylvania with their associated strata lying between the coal measure conglomerate and the Mahoning sandstone, or base of the Barren measures. At that time the conglomerate was supposed to be one solid bed of rock, subject only to local variations in thickness and in the proportion of sandstone to conglomerate.

But within the past five years a study of it has shown it to be a variable group of hard and soft strata, including workable coal beds with their under clays. It therefore properly forms a part of the Lower Productive Coal Measure Series: and only thus can the parallelism of the Ohio and Pennsylvania sections be made good.

Stated Meeting, April 1, 1881.

Present, 10 members.

Vice-President, Mr. E. K. PRICE, in the Chair.

Sig. Damiano Muoni signified his acceptance of membership, by letter dated Milan, January 20, 1881.

Mr. Joseph J. Lewis, accepted membership, by letter dated West Chester, March 24, 1881.

Letters acknowledging the receipt of Proceedings were received from the Philosophical Society at Glasgow, March 9 (106); the Fondation Teyler, Harlem, 3 Mars (105, 106 and List); the American Ethnological Society, New York, March 24 (107); and J. H. C. Coffin, Washington (107).

Letters of envoy were received from the Geological Survey of Pennsylvania, Harrisburg, March 29, and Dr. Peters, Kiel, February 23, 1881.

Dr. Nolan informed the Society by letter that a box of Indian relics had been sent to the care of the Academy of Natural Sciences, by Mrs. Haldeman, for the American Philosophical Society. On motion these were ordered to be deposited in the Academy's museum, and Dr. Horn was appointed to verify the list.

Donations for the library were reported from the Asiatic

Society of Japan; the Academies at St. Petersburg, Berlin, Rome and Philadelphia; the Bureau of Statistics of Sweden; the Zoologischer Anzeiger; Frankfurt Geographical and Statistical Association; Bordeaux Commercial Geographical Society; MM. Delesse and Lapparent, and Revue Politique of Paris; British Association, Royal Astronomical Society, Chemists' Journal and Nature; Nova Scotia Institute, Canadian Naturalist, Prof. Ed. C. Pickering, Hon. Robert C. Winthrop; the Middletown Scientific Association; the American Journal of Science; Mr. C. B. Dudley; Mr. H. C. Lewis; the Second Geological Survey of Pennsylvania, and the Johns Hopkins University.

A box of Indian flints for the cabinet sent from Chicques, Lancaster County, Pa., by Mrs. Haldeman, was reported in the care of the Academy of Natural Sciences, Philadelphia.

Rhætic flora. The Secretary reported that he had received letters from Prof. W. M. Fontaine, of the University of Virginia, dated Charlottesville, February 21st and March 29th, respecting the publication in the Transactions of a Memoir on the Rhætic flora, and on the formation to which they belong, in Virginia and North Carolina; about 340 pp. MS. with 32 4to plates, the figures closely placed, and nearly all in outline, with only indispensable details.

Besides the descriptions of plants, the author gives "a pretty full account of the geology of the Mesozoic of Virginia, with an explanation of its peculiar features." He has "a very large collection of fine plants. Many of them are new, some exceedingly fine; and all of them, whether already described or as yet undescribed, much more perfect than any hitherto found." "The collection is a pretty fair representation of the flora of the older Mesozoic, and will throw light on the Mesozoic of North Carolina and Pennsylvania."

Saltville fault. The Secretary communicated the following notes by Prof. Fontaine, made in the same letters, upon the views of Mr. H. C. Lewis respecting the structure of the Saltville valley in Southern Virginia, published in the Proceedings No. 107, page 155.

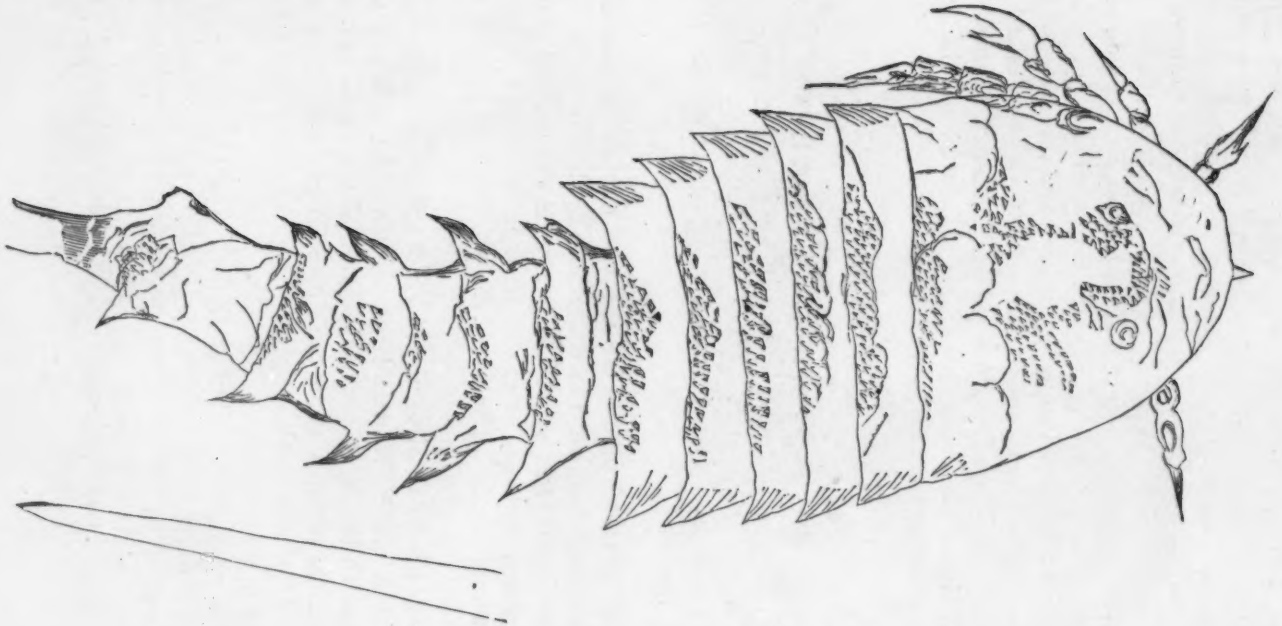
Mr. Fontaine points out that the little salt and gypsum bearing valley of Saltville cannot be "eroded along an anticlinal of Lower Silurian limestones," because the south-east wall hills only are of that age, while the north-west wall hills are of Umbral (Mauch Chunk, Subcarboniferous) age. He was the first to find in the limestones on that side of the valley an abundance of Umbral fossils, in the highly fossiliferous shale beds intercallated between the massive limestones. The species are the same found in the Umbral near Lewisburg, West Virginia. The Magnesian (Lower Silurian) limestone strata, bounding the valley on the south-east, show no trace of fossils.

The physical aspects of the two formations also differ. Beds of shale and limestone alternate in the hills N. W. of the valleys; and some of the limestone is cherty, and some of the shales are red. But the S. E. hills contain only solid limestone strata. Those on the N. W. side have a more rounded topography.

It is, however, quite true that the stratification is in opposite S. E. and N. W. directions; gentle to the S. E. and much steeper to the N. W. The structure is therefore anticlinal. But there must be a considerable fault along the axis of the anticlinal, and this fault must run along the south-east edge of the little valley.

The explanation is then simple. The Umbral limestone ridge is a synclinal; and the red shale formation comes up on both sides of it,—with north-west dips in the little valley,—and with south-east dips in the valley of the Holsten river, at the foot of the mountain, as shown above.

Amer. Philos. Soc. Proc., Vol. XIX, p. 152, April 1, 1881.



EURYPTERUS FROM DARLINGTON SHALES, PENN.

A reference to the place of the Michigan Salt group in the Palæozoic series makes the presence of salt here easily understood. The horizon seems to be salt-bearing in other places in Southern Virginia. There is a salt ooze near Max Meadows, at about this geological horizon.

The Secretary suggested, in addition, that the underlying Vespertine (Pocono) sandstone is a great salt producing formation in the Ohio river up-country. That the gypsum is an acid reaction upon the eroded outcrops of the limestone he showed in Proceedings A. P. S. Vol. IX. p. 34, 1862.

Mr. J. F. Mansfield of Cannelton, Beaver county, Pa., communicated by letter, dated House of Representatives, Harrisburg, February 4, 1881, a drawing, life size, of a fine fossil *Eurypterus* found by him in the shale immediately beneath the Darlington Cannel Coal bed, Lower Productive Coal measures, with a request to have the specimen studied and described.

Mr. E. B. Harden exhibited two models in plaster, one geologically colored, the other uncolored, of a large part of Blair county, Pa., on a scale of 8000′ : 1″; vertical scale exaggerated 2½ times.

Captain E. Y. McCauley, U. S. N., communicated for publication in the Proceedings an alphabet and syllabary of the Egyptian language, for the use of students, in 32 MS. pages, reducible to 8vo size for the Proceedings.

The Publication Committee reported in favor of a full exchange of all publications, so far as sets could be made, with those of the Musée Guimet at Lyons, which was approved and ordered.

Pending nominations 927 to 933 were read, and the meeting was adjourned.

Stated Meeting, April 15, 1881.

Present, 17 members.

President, Mr. FRALEY, in the Chair.

A photograph of Herr Göppert was received for the album, in a letter of envoy, dated Breslau, March 24, 1881.

Letters of acknowledgment were received from Herr Bernard Studer, dated Berne, March 25 (106 and List), and from the Zool. Soc. Amsterdam (105, 106 and List).

The Physical Section of the Ch. Phy. Soc. Imp. University of St. Petersburg was on motion placed on the list of correspondents to receive the Proceedings.

Donations for the Library were announced from the Russian Academy; Accad. dei Lincei at Rome; Society at Emden; Dr. Otto Wolfenstein of Valencia; Com. Geological Society, Bordeaux; Halifax Library Company; Prof. O. C. Marsh; Mr. Henry Phillips, Jr.; New Jersey Historical Society; Hamilton College, N. Y.; Wyoming Historical & Geological Society; American Journal of Pharmacy, and Am. Jour. Med. Sciences; U. S. Coast Survey; University of Virginia, and Major Jed. Hotchkiss.

A drawing and description of his improved "Centigrad Photometer" was received from D. Coglievina of Vienna.

Prof. P. E. Chase, explained certain relations of the spectrum line F with other lines and data suggesting the probable identity of hydrogen and the luminiferous æther.

Prof. Cope read a paper on the Perissodactyla.

Dr. König made remarks on Dr. P. F. Reinsch's recent plates of the misroscopic lithology of anthracite and other coals.

Mr. Lesley communicated an appendix to Dr. Spencer's paper on the Lake Erie former water-basin, suggesting the probable flow of the upper Ohio from Pittsburgh to Butler, thence, via New Castle, up the present Mahoning Valley and down the Grand Valley of Ohio to Lake Erie.

On scrutiny of the ballot boxes the President declared the following persons duly elected members of the Society.

Prof. Claudio Jannet, of Paris.

Prof. Paul Leroy Beaulieu, of Paris.

M. Emile Malézieux, of Paris.

Prof. E. A. Barber, of West Philadelphia.

Dr. Jas. A. H. Murray, of Mill Hill, London.

Hon. William Butler, Judge of U. S. District Court, Eastern District of Pennsylvania.

Mr. Wm. Woodnutt Griscom, of Philadelphia.

And the meeting was adjourned.

Photodynamic Notes, II. By Pliny Earle Chase, LL.D., Professor of Philosophy in Haverford College.

(*Read before the American Philosophical Society, April* 15, 1881.)

16. *Weighing the Sun by a Soap Bubble.*

In the well-known experiment of inflating a soap bubble with a mixture of oxygen and hydrogen, and exploding it by a candle, there is an opportunity for studying various radiodynamic relations. The equilibrium, which usually exists between the gravitation of the particles towards the sun and towards the earth, is suddenly and violently disturbed. During the restoration of equilibrium, there are simultaneous tendencies to the production of orbital velocities, about the earth and about the sun.

The height of virtual focal projection which represents elliptic orbital velocity is $\frac{r}{2}(1+e)$; the height at Earth's equatorial surface, which is in unison with orbital projection, being $\frac{3962.8}{2} \times 1.01677 = 2014.16$ miles. Dividing this height by the French thermal unit $\left(C = \frac{1389.6}{5280} \text{ mile-pounds}\right)$ and multiplying by 9, because 9 pounds of gas are lifted by 1 pound of combustible, we get 68878.2 calorics as the thermal equivalent of the explosion. Naumann* gives the following experimental values:

Thomsen	68376
Favre and Silbermann	68924
Dulong	69486
Hess	69584
Grassi	69332
Andrews	67616
Mean	68886

* Handbuch der Chemie, p. 290.

The explosive force proceeds radially in all directions from the centre, so that the particles are subjected to cones of force, introducing oscillations which may be represented by a conical pendulum of $\frac{1}{4}$ the height, or 503.54 miles. In seeking equilibrium, the particles tend towards their own centre of gravity, at $\frac{1}{2}$ of $503.54 = 251.77$ m., and also, on account of resistance at the Earth's surface, towards the linear centre of oscillation, at $\frac{2}{3}$ of $503.54 = 335.69$ miles.

The action of Earth on the centre of gravity of the mass produces a secondary centre of oscillation, in which the primary centre of oscillation acts as a point of suspension, and the centre of gravity as a pendulum-extremity of wave propagation. This secondary centre of oscillation is at $\frac{5}{9}$ of $503.54 = 279.745$ m., which represents the mean *vis viva* of oscillatory projection relatively to Earth; the *vis viva* relatively to Sun being represented by Earth's semi-axis major.

Let $r = 3962.8$ miles; $nr =$ Earth's semi-axis major; $t_0 = 1$ year $=$ 31558149 seconds; $t_1 = 2\pi\sqrt{\frac{r}{g}} = 5073.6$ sec.; $m_0 =$ Sun's mass; $m_1 =$ Earth's mass; $h = 279.745$ miles. Then we have

$$\left(\frac{nr}{r}\right)^3 : \left(\frac{t_0}{t_1}\right)^2 :: m_0 : m_1 :: nr : h,$$

$$\therefore m_0 = 331{,}631\ m_1$$

$$nr = 92{,}772{,}200 \text{ miles.}$$

17. *Centres of Density and of Nucleation.*

The rotating photodynamic action which is represented by the equations, $\frac{gt}{2} =$ *velocity of light*, $\frac{gt^2}{4} =$ *modulus*, is shown in its greatest simplicity at the nucleal centres of cosmical systems. In all other places it is complicated with orbital motions, which increase the difficulty of determining the sum of the photodynamic actions which are balanced by an equal sum of gravitating reactions. Doubtless methods will be found hereafter for making the proper allowances in all the most important cases; but at present we can take only a few steps towards the goal. The first step, naturally, is from Sun, the centre of nucleation, to Earth, the centre of density. Here we are helped, as in the first instance, by the study of maxima. The limit between association and dissociation at the nucleal centre is the velocity of light, or the greatest known velocity of wave propagation; the centre of density is revolving about the nucleal centre, and its "nascent" limit shows the greatest possible tendency to circular-orbital velocity in the system.

Earth's nascent velocity, if its orbit were strictly circular, would be $\frac{gt}{2} = \frac{86164}{2} \times \frac{32.088}{5280} = 261.82$ miles. This needs to be multiplied by $(1+e)^2 = (1.01677)^2$, in order to allow for orbital "subsidence" from aphelion to mean position. We thus get 270.68 miles, for the value of $\sqrt{gr}$ at Sun's equatorial surface. If we knew the precise quotient of Earth's

semi-axis major by Sun's semi-diameter, we could easily compute Sun's mass and distance. Different observers give measurements of Sun's diameter, which vary through a range of about a fourth of one per cent.

In expanding or condensing nebulæ, I have shown that Laplace's limiting or atmospheric radius varies as the $\frac{4}{3}$ power of the nucleal radius. Our first step towards transforming Earth's orbital into nucleal efficient velocity, is to multiply $\frac{gt}{2} \times (1 + e)^2$ by $(1 + e)^{\frac{4}{3}}$. We must also multiply by π, because the time of acquiring the efficient velocity is π times as great as the time of acquiring orbital velocity, and by n*, because Sun's equatorial velocity of rotation is n times as great as the corresponding velocity of rotation when expanded to Earth's orbit. We then have:

$$\text{Earth's } \frac{gt}{2} \times (1 + e)^2 \times (1 + e)^{\frac{4}{3}} \times \pi n = \textit{velocity of light} = 10089.15 \times 270.68 \div n^{\frac{1}{2}}.$$

The right-hand member of this double equation is obtained as follows:

If ρ = Earth's semi-axis major, its orbital velocity is $2 \pi \rho \div 31558149$; the velocity of light being $\rho \div 497.827$. But 270.68 is $n^{\frac{1}{2}}$ times Earth's orbital velocity; therefore, the velocity of light is $\left(\frac{31558149}{2 \pi \times 497.827} = 10089.15\right) \times 270.68 \div n^{\frac{1}{2}}$.

Solving the equation, we find: $n = 214.4775$; $v_\lambda = 186{,}385.7$; $\rho = 497.827$ $v_\lambda = 92{,}787{,}850$ miles; $m_0 = \left(\frac{\rho}{3962.8}\right)^3 \div \left(\frac{1 \text{ yr.}}{5073.6 \text{ sec.}}\right)^2 = 331{,}799\ m_1$.

This purely photodynamic determination of ρ differs by less than $\frac{1}{39}$ of one per cent. from the partially thermodynamic determination in the foregoing note.

18. *Nucleal and Rupturing Centres of Condensation.*

Our next tentative step is to Venus, the nearest and brightest of Earth's sister planets, and the only one which shares with Earth the peculiarity of sometimes having an orbit, in the course of its secular changes of excentricity, which is entirely circular. This fact, together with Earth's central position in the dense belt, indicates a purely nucleal origin for that belt; the other planets showing more obvious evidences of an origin which was partly atmospheric, and of the influences of "subsidence" which were so happily pointed out by Herschel. The nascent *vis viva* of Venus, $\left(\frac{gt}{2}\right)^2_\beta$, was also a rupturing *vis viva* in the dense belt, as is shown by the following relation between Earth's semi-axis major, ρ_a, and Venus's secular perihelion radius-vector, ρ_β.

$$\left(\frac{gt}{2}\right)^2_a : \left(\frac{gt}{2}\right)^2_\beta :: \rho_a : \rho_\beta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1.)$$

*n represents the quotient of Earth's semi-axis major by Sun's semi-diameter.

Let us take for m_a the value given by Note 17; for m_β, Hill's estimate, $\frac{1}{427840}$; for t_a, $23^h\ 21^m = 84060$ sec. Then

$$\frac{42030}{427840} \times \frac{1}{r_\beta^2} = \left(\frac{gt}{2}\right)_\beta \quad \ldots\ldots (2.)$$

$$\frac{43082}{331799} \times \frac{1}{r_a^2} = \left(\frac{gt}{2}\right)_a \quad \ldots\ldots (3.)$$

Introducing Stockwell's value, $\rho_\beta = .672241$, together with (2) and (3), into (1), we have

$$\left(\frac{43082}{331799} \times \frac{1}{r_a^2}\right)^2 \times .672241 = \left(\frac{42030}{427840} \times \frac{1}{r_\beta^2}\right)^2$$

Hence we find:

$$r_\beta = .9606\ r_a.$$

Herschel gives .983; Newcomb and Holden, .967; Newcomb, in Johnson's Cyclopædia, .9602; Searle, .96; Chambers, .948.

19. *Centres of Density and Nebulosity.*

Earth's nascent relation to the maximum value of Sun's $\sqrt{gr}$ introduces, as we have seen, the factor of gravitating subsidence to a spheroidal nucleus, $(1 + e)^2$. Jupiter's relation to the same value, indicates the formation of a secondary nucleus, at the centre of primitive nebulosity; for Sun's superficial $\sqrt{gr}$, 270.68, is accelerated, in Jupiter's nascent velocity, in the ratio which is due to solar condensation to Jupiter's secular perihelion, or rupturing atmospheric locus, which is .9397 of its semi-axis major, the greatest eccentricity being .0603. We have, therefore:

$$\left(\frac{gt}{2}\right)_\gamma = (\sqrt{gr})_0 \div .9397 = 288.076 \text{ miles.}$$

Professor Hall's estimate of t_γ is $9^h\ 55^m\ 26^s.5 = 35726.5$ seconds. This gives $g_\gamma = 288.076 \div \frac{t_\gamma}{2} = .016127$ m. $= 2.654\ g_a$; $r_\gamma^2 = \left(\frac{m}{g}\right)_\gamma = \left(\frac{331799}{1047.879} \div 2.654\right) r_a^2$; $r_\gamma = 10.924\ r_a$.

Herschel gives 10.977; Newcomb, 10.85; Searle, 10.93; Chambers, 10.75.

20. *Central Nebulous Rupture and Subsidence.*

The co-ordinate influence which is shown in the nascent velocities of Earth and Venus (Note 18). has an analogue in Jupiter and Saturn. If we represent Jupiter's atmospheric rupturing locus by ρ_γ, and Saturn's locus of incipient subsidence, or secular aphelion, by ρ_δ, we find:

$$\rho_\delta : \rho_\gamma :: (\sqrt{gr})_0 : \left(\frac{gt}{2}\right)_\delta$$

$$10.343 : 4.8863 :: 270.68 : 127.81.$$

Prof. Hall's estimate of t_δ is $10^h\ 14^m\ 23^s.4 = 3683.4$ seconds. Dividing 127.81 miles by $\frac{t_\delta}{2}$, we get $g_\delta = .0069344$ m. $= 1.141\ g_a$; $r^2{}_\delta = \left(\frac{331799}{3501.6} \div 1.141\right) r^2{}_a$; $r_\delta = 9.113\ r_a$.

Herschel gives 9.87; Newcomb, 8.86; Searle, 9.01; Chambers, 9.07.

21. *Nodal Coördination.*

We see, therefore, from Notes 17–20, that the five nodal positions, which are of the greatest photodynamic importance in the solar system, show successive coördinating influences of universal æthereal oscillation; for, if we designate nascent velocity $\left(\frac{gt}{2}\right)$ by V,

V_o, or the sum of the reactionary gravitating impulses at Sun's surface during a half-rotation, is the velocity of light.

V_a, or the sum of the reactionary gravitating impulses at Earth's surface during a half-rotation, is due to the sum of the reactionary impulses at Sun's surface during the time of communicating orbital velocity, $\sqrt{\frac{r}{g}}$; part of the velocity being compensatory of orbital subsidence, and the rest giving axial rotation.

V_β, or the sum of the reactionary gravitating impulses at Venus's surface during a half-rotation, is due to the belt-rupturing impulses of the reactionary impulses at Earth's surface.

V_γ, or the sum of the reactionary gravitating impulses at Jupiter's surface during a half-rotation, is due, in part, to the sum of the reactionary impulses at Sun's surface during the time of communicating orbital velocity, and in part to the acceleration of Sun's atmospheric condensation to the locus of nebular rupture.

V_δ, or the sum of the reactionary gravitating impulses at Saturn's surface during a half-rotation, is the incipient velocity which, when accelerated by solar atmospheric subsidence to the rupturing locus of its belt, became equivalent to the sum of the reactionary impulses at Sun's surface during the time of communicating orbital velocity.

The joint relations of Earth's eccentricity, Earth's semi-axis major, Sun's semi-diameter, the velocity of light, planetary velocity, nascent velocity of Sun and Earth, and Sun's equatorial velocity of rotation, which are shown in Note 17, are wholly inexplicable upon any hypothesis which fails to recognize the equal actions and reactions of an elastic medium. They are all, however, simple and natural results of photodynamic influence. Sun's nascent velocity is the velocity of light, V_0; the limit of circular-orbital velocity ($V_1 = (\sqrt{gr})_0 = 270.68$ miles), is equivalent to $V_0 \div (1+e)^{\frac{3}{2}}\pi n$; Earth's nascent velocity $\left(\frac{gt}{2}\right)_a = 261.82$ miles, is equivalent to $V_1 \div (1+e)^2$; Sun's equatorial velocity of rotation ($V_2 = 1.233$ miles), is equivalent to $\frac{(1+e)^{\frac{3}{2}}}{n} \times \left(\frac{gt}{2}\right)_a$.

22. *Boundaries of the Dense Belt.*

The uncertainty of Mercury's mass makes any attempt to determine its nascent velocity merely provisional. It seems probable, however, that it bears the same proportion to Earth's nascent velocity as Mercury's radius

of incipient subsidence, or secular perihelion (.477), bears to Earth's semi-axis major. If such is the case, it furnishes another instance, like the inner moon of Mars, of the establishment of a nucleolus, by subsidence within a condensing nucleus. If we take Encke's mass, $\frac{1}{4865751}$, and Herschel's time, $t = 24^h\ 5^m$, the proportion

$$.477 : 1 :: \left(\frac{gt}{2}\right)_\varepsilon : \left(\frac{gt}{2}\right)_a$$

gives $$r_\varepsilon = .379\ r_a.$$

Herschel gives .396; Newcomb, .378; Searle, .34; Chambers, .374.

Mars, the outermost of the dense belt of planets, furnishes clear evidence of the dependence of nascent velocity upon photodynamic influence. If we designate the centripetal photodynamic acceleration at Earth's semi-axis major by ϕ_a, and the action at the mean secular aphelion of Mars by ϕ_η, we find

$$\left(\frac{gt}{2}\right)_a : \left(\frac{gt}{2}\right)_\eta :: \phi_a : \phi_\eta :: 1.64416^2 : 1^2$$

Substituting Hall's values for m_η, $\left(\frac{1}{3093500}\right)$, and t_η, ($24^h\ 37^m\ 22^s.7$), we get $$r_\eta = .546\ r_a$$

Herschel gives .517; Newcomb, .531; Searle, .53; Chambers, .621.

23. *Fourier's Theorem.*

In the activities of the luminiferous æther we may reasonably look for abundant evidences of the truth of Fourier's theorem: "Every periodic vibratory motion can always, and always in one manner, be regarded as the sum of a certain number of pendulum vibrations."* In Note 5, I gave an estimate of the mass at the centre of condensation, which was based upon this theorem. The same value may also be obtained as follows: If we consider simple lines of force, in homogeneous nebular condensation, we find the centre of gravity coincident with the linear centre, and the centre of oscillation at two-thirds of the distance from a point of suspension, or principal inertia, to a point of oscillation, or inferior inertia. If we consider radial action from or towards a centre, we know that the oscillations of a conical pendulum are synchronous with those of a linear pendulum of four times the length. We know, moreover, that centripetal acceleration varies as the fourth power of the velocity of circular orbital revolution. In the conversion of tendencies to nucleal rotation into tendencies to orbital revolution, the oscillating particles are, therefore, subjected to central influences which may be represented by $(2 \times 3 \times 4)^4 = 331776$, which is the ratio of the mass at the centre of nucleation to the mass at the centre of condensation, as estimated in Note 5. It differs by less than $\frac{1}{2\frac{1}{2}}$ of one per cent. from the value found in Note 16, and by less than $\frac{1}{1\,4\,4}$ of one per cent. from the value found in Note 17.

* Prof. Mayer's statement of the theorem, in Am. Jour. Sci. [3], viii, 85.

24. *Satellite Velocity at the Centre of Density.*

The influence of Laplace's limit appears in satellite velocity as well as in velocity of rotation (Note 17), at the centre of condensation in the solar system; thus lending added significance to the stellar-solar paraboloids.* If l designates the limit of synchronous rotation and revolution, it is evident, from Kepler's third law, that $\pi\, l^{\frac{3}{2}}\, (gr)^{\frac{1}{2}} = \frac{gt}{2}$, and $\pi^2\, n\, l^{\frac{3}{2}}\, (gr)^{\frac{1}{2}}\, (1+e)^{\frac{10}{3}} =$ *velocity of light.* If we take Earth's semi-axis major as the unit-length of linear oscillation, the velocity which corresponds to the mean linear *vis viva* is $\left(\frac{2}{3}\right)^{\frac{1}{2}}$; the accelerating limit of satellite velocity divided by velocity of equatorial rotation is $\frac{86164}{5073.6} = 16.9828$; the nascent *vis viva* of nebular atmospheric condensation divided by mean orbital *vis viva* is $[\pi\, (1+e)^{\frac{1}{3}}]^2$; the *vis viva* of terrestrial projection, in units of nucleal condensation, is n. The projection against uniform resistance, or the synchronous rotating velocity which is due to such projection, is proportioned to the *vis viva*, and we find that

$$\left(\frac{2}{3}\right)^{\frac{1}{2}} : 16.9828 :: \pi^2 \times 1.01677^{\frac{5}{3}} : n = 214.59$$

This value of n differs by less than $\frac{1}{15}$ of one per cent. from the one found by Note 17. Such accordance in the successive transformations of photodynamic energy into energy of rotation and of revolution gives new evidence of the kinetic importance of Earth's position at the centre of belt-condensation.

If we treat e and n as unknown quantities, and find their values by combining the methods of Notes 17 and 20, we get $1 + e = 1.01662$; $n = 214.51$. This value of e differs by less than $\frac{1}{85}$ of one per cent. from the observed value, 1.01677. If we treat n and the constant of aberration as unknown quantities, we find $n = 214.59$; time of light propagation from Sun, 497ˢ.423.

25. *Satellite Velocities in the Dense Belt.*

The equation, $\pi l^{\frac{3}{2}}\, (fr)^{\frac{1}{2}} = \frac{ft}{2}$, is true in all cases of radiodynamic centrifugal or centripetal influence, whether cosmical or molecular. The range of uncertainty respecting the masses, densities, and axial rotations of the other planets, is too great to justify any attempts at precise measurement of their dependence upon æthereal or photodynamic influence, but some interesting comparisons may be drawn between the central and collateral energies in each of the great planetary belts, which furnish suggestive indications for future precise observation and analysis. If we refer the satellite velocities of the dense belt to photodynamic energy at the centre of the belt, by taking Earth's limiting velocity as the unit, we may designate the limiting velocities for Mercury, Venus, Earth, and Mars, by v_1, v_2, v_3, v_4,

* Proc. Am. Phil. Soc., xii, 518; xix, 298; *et al.*

respectively. These velocities vary as $\left(\frac{m}{r}\right)^{\frac{1}{2}}$, and if we take the values of r which were found by comparing the axial periods, with the values of m, which were assumed in comparison (Notes 17, 18, 22), we find :

$v_3 : v_1 :: 1 : .4242$	Mercury's semi-axis major		.3871
$v_3 : v_2 :: 1 : (.7255)^{\frac{1}{2}}$	Venus's	" "	.7233
$v_3 : v_4 :: 1 : (1 \div 1.502)^2$	Mars's	" "	1.5237

All of these ratios point to influences operating within the orbits of the respective planets. The ratio between Earth and Mercury indicates simultaneous nucleolar condensation within a primitive condensing nucleus; the ratio between Earth and Mars indicates the comparative influence of centripetal photodynamic impulsion, or of orbital gravitation towards the Sun; the ratio between Earth and Venus indicates synchronous harmonic influences of projectile *vis viva* within a rotating nebula.

26. *Satellite Velocites in the Rare Belt.*

Extending the foregoing comparison to the lighter planets, we find :

$v_3 : v_5 :: 1 : 5.3838$	Jupiter, mean aphelion		5.4274
$v_3 : v_6 :: 1 : (10.3937)^{\frac{1}{2}}$	Saturn, secular	"	10.3433
$v_3 : v_7 :: 1 : 2.0308$	Relative momentum,		29.812
$v_3 : v_8 :: 1 : 1.7271$	"	"	29.567

Jupiter, therefore, falls into the same category as Mercury and Earth, as indicating simultaneous nucleolar condensation within a primitive condensing nucleus; the ratio between Saturn and Earth indicates satellite velocities accordant with their respective velocities of nucleal projection; the Uranian and Neptunian ratios multiplied by their respective mass-ratios, point to a primitive unity of momentum near the outer surface of our system in its early stages of condensation.

If we adopt Newcomb's values for the respective masses of Uranus and Neptune, $\frac{1}{22600}$ and $\frac{1}{19380}$, and take Earth's mass, $\frac{1}{331795}$, for the unit of comparison, we find

	Mass.	Limiting sat. v.	m × v.
Earth,	1	1	1
Uranus,	14.68	2.0308	29.812
Neptune,	17.12	1.7271	29.567

Stockwell gives 29.732 for Neptune's mean perihelion, or rupturing locus, so that Earth's relative momentum : the rupturing momentum :: Earth's mean radius vector : the rupturing radius vector. This seems to be a conclusive evidence of a common rotating influence which embraces the centre of nucleation, the centre of density and the Neptuno-Uranian belt.

27. *Harmonic Relations of the Moon.*

In Note 8, the Moon's mass was shown to be in strict accordance with the requirements of radiodynamic elasticity. The two foregoing notes,

together with the Moon's position relative to the centre of density, make it probable that its distance from the Earth, as well as its mass, may furnish important harmonic indications. We find, accordingly, the following close approximations :

Sun's distance : Moon's distance :: Jupiter's mean locus of subsidence (mean aphelion) : Sun's radius of condensation :: Neptune's mean rupturing *vis viva* : Earth's nebular *vis viva*. This triple proportionality is satisfied by the following values :

$$92,996,000 : 238,847 :: 1168.07 : 3 :: (19.73)^2 : 1$$

This would give 215.22 for the quotient of Earth's semi-axis major by Sun's semi-diameter, which is probably about $\frac{1}{3}$ of one per cent. too large. These slight differences in the approximations to the value of n may be due to solar atmospheric, photospheric and chromospheric modifications.

The approximation of Moon's semi-axis major, measured in units of Earth's semi-diameter (60.28) to the continued product $3 \times 4 \times 5$, is also noteworthy.

28. *The Moons of Mars.*

The linear-pendulum ratio, 3, which was introduced twice in the foregoing note, appears in a vast number of satellite, planetary, stellar and molecular harmonies. The following table, with its influence upon the moons of Mars, is a very striking instance :

3^0	=	1
$3^1 - 3^0$	=	2
$3^2 - 3^1 - 3^0$	=	5
$3^3 - 3^2 - 3^1 - 3^0$	=	14
$3^4 - 3^3 - 3^2 - 3^1 - 3^0$	=	41

The above numbers are harmonic divisors, in the Mavortian system, of a primitive nebular radius which represents proportionate action between the centre of photodynamic planetary inertia (Saturn) and the locus of internal rupture in the dense belt (Venus's mean perihelion). For we have

Saturn, mean rad. vec. : Venus, mean per. :: 9.539 : .698 :: 13.67 : 1

If we take 13.67 semi-diameters of Mars as the nebular radius, $\frac{1}{2}$ the radius would be the locus of primitive rupturing subsidence, a locus which accords very closely with the semi-axis major of Deimus, the outer satellite. This and other accordances are shown in the following table :

Divisors.	Quotients.	Observed Positions.	
1	13.670	13.670	Nebular radius.
2	6.835	6.846	Deimus.
5	2.734	2.730	Phobus.
14	.976	1.000	Semi-diameter.
41	.333	.333	Linear c. of central oscill'n.

The importance of the ratio of harmonic undulation, which has been thus introduced at the outer limit of the dense belt, has a deeper meaning, when we remember that Venus and Earth are the only two planets whose

orbits are ever exactly circular, and therefore the only ones that indicate nebular activities which extend to the very surface of a rotating nucleus.

29. *The Moons of Jupiter.*

We may reasonably look for a greater variety of satellite harmonies in connection with the giant planet which represents the primitive nebular centre of our system, than in connection with any of its subordinate companions. Some of those harmonies have been already indicated in Note 14. It may be well to restate two of them in a different form, together with some others which seem especially significant.

I. If we take axial rotation at the centre of density as the unit of comparison, the synchronous rotation and revolution of the nebular hypothesis has been accelerated 366.2565 fold, by Earth's condensation and other causes. Earth's accelerated rotation, is to the acceleration by fall to a centre of linear oscillation, as Jupiter's synchronous radius is to Callisto's synchronous radius:

$$366.2565 : 9 \cdot : 4332.5848^{\frac{2}{3}} : 16.6891^{\frac{2}{3}}$$

The significance of this rhythmical accordance between the nebular centre and the centre of density is increased by the fact that the nascent velocity at each of those centres is directly traceable to the maximum of planetary velocity ($\sqrt{gr}$ at Sun's surface).

II. The significance is further increased by the fact that Callisto represents the mean centre of gravity of Earth and Jupiter, at Jupiter's rupturing locus. Jupiter's mean perihelion being 4.9782, its distance from Earth's semi-axis major is 3.9782. Jupiter's mass being $\frac{1}{1047.88}$, this relation gives $\frac{1}{331245}$ for Earth's mass, as will be seen in the following proportion, .012585 being Callisto's semi-axis major:

$$3.9782 : .012585 : : \frac{1}{1047.88} : \frac{1}{331245}$$

This estimate of Earth's mass gives 92,736,000 miles for Earth's semi-axis major, and 1,167,100 miles for Callisto's semi-axis major.

III. The harmony of planetary and satellite influences, at the centres of density and of nebulosity, is shown by the proportion,

Jupiter's secular perihelion : Earth's semi-axis major : : Callisto's semi-axis major : Moon's semi-axis major.

$$4.8863 : 1 : : 1{,}167{,}100 \text{ miles} : 238{,}850 \text{ miles}.$$

Herschel's estimate is		237,000 miles.
Lockyer's	"	238,793 "
Chamber's	"	238,830 "
Von Littrow's	"	238,870 "
Newcomb's	"	240,300 "

IV. An elliptic orbital influence, between Jupiter and the dense belt, with a major-axis of 6.131, is indicated by the proportion:

$$6.131 : .012585 : : 186282 : 382.38.$$

PROC. AMER. PHILOS. SOC. XIX. 108. 2T. PRINTED MAY 3, 1881.

The second term of this proportion represents Callisto's semi axis major; the third term, the velocity of light; the fourth term, the velocity acquired by infinite fall to Sun's surface.

V. The pendulum-factor, 3, appears in the Jovian system, in a primitive radius $= 3^3 \times 1.423 = 38.424$ semi-diameters, 1.423 being the theoretical ratio of the radius of constant volume to the radius of constant pressure.*

The following table shows the influence of harmonic vibrations upon the positions of Jupiter's satellites. The harmonic divisor for Callisto is very nearly $1 + 2a$; the other theoretical divisors have a constant third difference of a.

Theoretical Harmonic Divisors.	Observed Divisors.	Quotients.	
$1 = 1.000$	1.000	48.424	Gaseous radius.
a			
$a \quad 1 + \frac{a}{2a}$	1.428	26.998	Callisto.
$2a \quad 1 + \frac{3a}{4a}$			
$3a \quad 1 + \frac{7a}{7a}$	2.497	15.350	Ganymede.
$4a \quad 1 + \frac{14a}{11a}$	3.994	9.624	Europa.
$5a \quad 1 + \frac{25a}{16a}$	6.346	6.353	Io.
$6a \quad 1 + \frac{41a}{22a}$			
$7a \quad 1 + \frac{63a}{29a}$			
$8a \quad 1 + \frac{92a}{37a}$			
$9a \quad 1 + \frac{129a}{46a}$			
$1 + 175a$	38.424	1.000	Semi-diameter.

30. *The Moons of Saturn.*

The photodynamic centre of planetary inertia presents the following evidences of the influences of æthereal undulation:

I. Titan, Saturn's giant moon, bears witness to the rupturing tendencies at the centres of nebulosity and of planetary inertia, in the proportion:

Saturn's secular perihelion : Jupiter's mean perihelion : : Titan's semi-axis major : Sun's semi-diameter.

$$8.7344 : 4.9782 :: .00817 : .00466.$$

II. The combined influences of orbital revolution at the centre of density, and of Laplace's tendencies to synchronism, are shown in the approximate equivalence of the terrestrial year to 23 orbital revolutions of Titan.

$366.2565 = 23 \times 15.924$; Titan's orbital period $= 15.945$ days.

* Proc. Am. Phil. Soc. xiv, 651.

III. Saturn's satellite system presents two sets of harmonic indications, Titan's mass being so great as to establish an independent series of divisors.

	Distance.	Divisors.	Harmonic Divisors.	
Japetus,	64.359	1.000	1.000	
Hyperion,	26.795	2.402	2.397	$= 1 + a$
Rhea, aphelion,	9.747	6.603	6.588	$1 + 4\,a$
Dione,	6.821	9.436	9.384	$1 + 6\,a$
Tethys,	5.325	12.087	12.179	$1 + 8\,a$
Enceladus,	4.300	14.966	14.974	$1 + 10\,a$
Mimas,	3.351	19.206	19.166	$1 + 13\,a$
Japetus,	64.359	1.000	1.000	
Titan,	22.084	2.914	2.920	$= 1 + b$
Rhea,	9.526	6.756	6.760	$1 + 3\,b$
Semi-diameter,	1.000	64.359	64.359	$1 + 33\,b$

31. *The Moons of Uranus.*

The outer moon of Jupiter, the giant moon of Saturn, and the inner moon of Uranus are the ones which give the most direct testimony to the harmonic influence of planetary oscillations. The primary satellite-harmony is determined by the joint influence of Jupiter, Earth and Sun, in the systems of Earth and Jupiter; Saturn, Venus and Sun, in the system of Mars; Jupiter, Saturn and Sun, in the Saturnian system; Jupiter, Uranus and Sun, in the system of Uranus. The nucleal centre has, therefore, modified all the systems; the centre of nebulosity, all but the systems of Mars and Neptune; the centre of planetary inertia, its own system and that of Mars; the centre of condensation, its own system and that of Jupiter. The influence of each planetary radius appears in its own system; the influence of the radius vector also appears, except in the case of Mars, the outer planet of the dense belt, which shows the interaction of mean planetary inertia in the outer belt and internal rupturing tendencies in the inner belt.

I. The mean rupturing locus of Uranus : Jupiter's mean locus of subsidence :: Sun's semi-diameter : Ariel's semi-axis major.

$$18.323 : 5.427 :: .00466 : .00138.$$

II. The outer moon of the Uranian system represents, within less than two per cent., the retarded extremity of a linear pendulum, of which the inner moon represents the centre of oscillation. The harmonic divisor for the second moon, as in the Jovian system, is of the form $1 + 2\,a$. The subsequent differences are multiples of 5, the range between $1 + 2\,a$ and $1 + 127\,a$ being $5^3\,a$. The harmonic details are shown in the following table:

	Distance.	Divisors.	Harmonic Divisors.	
Oberon,	22.75	1.000	1.000	
Titania,	17.01	1.337	1.343	$= 1 + 2\,a$
Umbriel,	10.37	2.194	2.199	$1 + 7\,a$
Ariel,	7.44	3.058	3.055	$1 + 12\,a$
Semi-diameter,	1.00	22.750	22.750	$1 + 127\,a$

32. *Neptune's Moon.*

Is Neptune the outer limit of our planetary system, or may we look for still more distant members of our family of circling orbs? Astronomers find indications of some further source of remote perturbation, and attempts have already been made by Prof. George Forbes and D. P. Todd to furnish a clue to its discovery. More than eight years ago, I communicated to the American Philosophical Society* a planetary series which introduced the ratio of the circumference of a circle to its diameter, which is also the photodynamic ratio, at Sun's surface, between the reactions which represent the velocity of light and the reactions which represent the maximum of planetary velocity at Laplace's limit. The two terms of the series which immediately follow Neptune are 94.38 and 296.52 times Earth's semi-axis major. Forbes, by investigating the perturbations which are indicated by the aphelia of comets, has strikingly corroborated this forecast. The abstract of his memoir read before the Royal Society of Edinburgh says†: "On tabulating the aphelion distances of all the known elliptic orbits of comets, it was found that in no case was there any grouping of aphelion comet distances which did not agree with the distances of planets, except that beyond the distance of Neptune there were two groupings of comet aphelion-distances, one at 100 Earth's radii, the other at 300 Earth's radii, approximately." The perihelion or rupturing positions which are indicated by his investigations are 96.7 and 285.2.

Both of these investigations were entirely independent of my own, and neither of the writers gives any indication of ever having read my paper. There is, therefore, cumulative and conclusive evidence of harmonic influences, beyond the known limits of the planetary system as well as between the interior limits of the system and the Sun. The similarity of those influences, their dependence upon photodynamic action, and their importance as guides to investigation, are shown in the following note (33).

Neptune's satellite-harmony is the only one which involves the consideration of only two of the members of the system, Sun and itself. This fact, as well as the slight secular eccentricity of Neptune's orbit, seems to render it probable that the supra-Neptunian harmonies may indicate asteroidal rather than planetary aggregation. If Neptune represents the primitive belt of subsidence-collision, the corresponding nebular radius was $\frac{3}{2} \times$ its secular aphelion radius-vector, or $45.704 \times$ Earth's semi-axis major. We find, accordingly, that

I. Sun's mass : Neptune's mass : : Nebular radius : Neptune's lunar radius-vector.

$$19380 : 1 : : 45.704 : .00236.$$

II. Sun's semi-diameter : Neptune's lunar radius : : Modulus of light : virtual projection of light-velocity, *very nearly; i. e.*, within 1.3 per cent.

$$.00466 : .00236 : : 1 : .5065.$$

* Proceedings A. P. S., xiii, 140; Feb. 7, 1873.
† The Observatory, No. 38, p. 441.

33. *Infra-Mercurial Photodynamic Nodes.*

In my original anticipation* of harmonic nodes between Mercury and the Sun, I looked for possible unknown planets, planetoid groups, or other seats "of solar and planetary perturbation." The announcement† to the Royal Society, seven weeks afterward, of a sun-spot period which was synchronous with the revolution of the first infra-Mercurial node, furnished conclusive evidence of the predicted perturbations; the observation of supposed planetoid bodies, by Watson and Swift, rendered it probable that some of the perturbation is due to actual planetoid influences; the discussions of planetoid sun-spots, by Kirkwood, Mouchez, Gaillot, and Von Oppolzer, indicated four additional periods‡ in close accordance with four other harmonic nodes; a sixth node (.139) marks the locus (.140) of orbital time, which is a mean proportion between Earth's day and year; the six inner nodes have important photodynamic relations which merit special consideration.

The *vis viva*, and consequently the modulus of the velocity of any revolving particle, varies inversely as the radius vector. Hence, the photodynamic modulus of aggregating velocity (M_λ) : modulus of reacting mass (M_μ) : : radius of reacting mass (r_μ) : radius of aggregating velocity (r_λ). The quotient of modulus by the radius of rotation is equivalent to $(\pi\nu)^2$, ν being the quotient of $\sqrt{gr}$ by the velocity of rotation. The controlling bodies of the system are Sun and Jupiter, and if we take Jupiter's mass as the revolving unit of mass, Sun, the reacting mass, will be represented by 1047.879. If n designates the quotient of Earth's semi-axis major by Sun's radius (r_μ), $M_\lambda = \left(\frac{31558149}{497.827 \times 2\pi n^{\frac{1}{2}}}\right)^2$; $M_\mu = (\pi \times 1047.879)^2$. If $n = 214.5$, $M_\lambda = (688.873)^2$; $\nu = 688.873 \div \pi = 219.28$: $r_\lambda = M_\mu \div M_\lambda = 22.84$; the time of revolution at Sun's surface (t_0) = 31558149 sec. $\div 214.5^{\frac{3}{2}} = 10045.5$ sec.; the time of solar half-rotation, or the time in which gravitating reaction $\left(\frac{gt}{2}\right)$ against photodynamic action equals the velocity of light, $(t_\lambda) = \frac{\nu}{2} t_0 = 12.747$ days; r_λ is the locus which I have designated as Helios,§ or the distance at which a planet would revolve in t_λ. This gives, for the fundamental radius of my harmonic forecasts, 3.5134 × Earth's semi-axis major, which exceeds Jupiter's mean locus of subsidence collision ($\frac{2}{3}$ of 5.2028) by less than 1.3 per cent. The closeness of the independent verifications, by various observers, is shown in the following table:

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* Proc. Am. Phil. Soc., xiii, 238; New York Tribune, May 2, 1873.

† Proc. Am. Phil. Soc., xiii, 470.

‡ Ib. xviii, 35, 209.

§ Proc. Am. Phil. Soc., xviii, 35.

Harmonic Prediction.		Calculation from Observation.	
$\frac{1}{1}$	= 3.513	Node of subsidence,	3.513
$\frac{1}{3}$	.703	Venus, mean perihelion,	.698
$\frac{1}{9}$	.390	Mercury,	.387
$\frac{1}{13}$	.270	De LaRue, S. and L.,	.267
$\frac{1}{17}$	.207	Kirkwood,	.209
$\frac{1}{19}$	.185	Gaillot, (Watson, II)	.180
$\frac{1}{21}$	.167	Gaillot & M., (Watson, I)	.164
$\frac{1}{25}$	.141	Chase,	.140
$\frac{1}{29}$	.121	Von Oppolzer,	.123

I. The first of the six inner nodes, is $r_\lambda = 22.84$ Sun's semi-diameters, or nearly $= \frac{1}{33}$ Node of subsidence $= .1065$ Earth's semi-axis major. The others are found as follows:

II. $1 \div 366.2565^{\frac{2}{3}}$	$= .0195$	Earth's semi-axis major.
III. $(9^h\ 55^m\ 26^s.5 \div 1\text{ year})^{\frac{2}{3}}$	$= .0109$	" " "
IV. $2^{\frac{2}{3}} \div 214.5$	$= .0074$	" " "
V. $\left(\frac{4}{3}\right)^{\frac{2}{3}} \div 214.5$	$= .0057$	" " "
VI. $1 \div 214.5$	$= .0047$	" " "

All of these nodes represent synchronous oscillations which are due to mutual actions and reactions among the three important centres of nucleation (Sun), condensation (Earth), and nebulosity (Jupiter). While they are all, unquestionably, radiodynamic, their simple dependence upon the equality between Sun's nascent velocity and the velocity of light obviously refers them to the photodynamic branch of radiodynamics. Can any good reasons be given for regarding them as in any sense thermodynamic or electrodynamic?

The accordance of these six inner nodes of synchronism with the harmonic nodes, is shown in the following table:

	Harmonic nodes.	Synchronous nodes.	
I.	$\frac{1}{33} = .1065$	.1069	Velocity of light.
II.	$\frac{1}{177}$ .0199	.0195	Earth's day.
III.	$\frac{1}{321}$ .0109	.0109	Jupiter's day.
IV.	$\frac{1}{465}$ .0076	.0074	Two revolutions at r_μ.
V.	$\frac{1}{609}$ .0058	.0057	Solar subsidence.
VI.	$\frac{1}{753}$ .0047	.0047	Sun's semi-diameter.

34. *Photodynamic Projection of Hydrogen.*

The principles which are involved in Note 16 and in the first synchronous node of the foregoing note, are further illustrated by the simple relations which the molecular velocity of hydrogen bears to the velocity of light (v_λ), the velocity of equatorial solar rotation (v_r), and Earth's secular eccentricity. The reaction of gravitation against photodynamic action, at the centre of any stellar system, requires that

Modulus of light : Stellar semi-circumference :: $v_\lambda : v_r$.

The projections of hydrogen in solar explosions, together with the many indications that hydrogen represents the first known stage of æthereal condensation, make it probable that Earth's orbital projection $\left(p = \frac{1+e}{1-e}\right)$, and the molecular velocity of hydrogen (v_h) may also be directly dependent upon photodynamic action. Such dependence is shown by the equation

$$p\, v_h = v_r.$$

The secular value of p, according to Stockwell, is $\frac{1.0338}{.9662} = 1.06994$; molecular velocity of hydrogen v_h, at the temperature of maximum water-density, is $\sqrt{\frac{277}{273}} \times 6050 = 6094.14$ ft. $= 1.1542$ miles; hence v_r, or Sun's equatorial velocity of rotation, $1.06994 \times 1.1542 = 1.235$ miles. Multiplying by the number of seconds in 12.747 days (t_λ, see foregoing note) and dividing by π, we get 432,931 miles for Sun's semi-diameter, and $214.5 \times 432{,}931 = 92{,}863{,}700$ miles for Earth's semi-axis major. These relations, also, are photodynamically radiodynamic, but it would be difficult to find in them any evidence of thermodynamic or electrodynamic action.

35. *Æthereal, Gaseous and Planetary Densities.*

I have already given two approximations* to the comparative æthereal ratio of elasticity to density, and one approximation† to the relative densities of æther and hydrogen. The accumulating evidences of universal photodynamic energy, leading to various accordant æthereal, gaseous and cosmical harmonies, are such as to justify another tentative step in the same direction. From chemical analogy the planetary aggregations, at the centres of nebulosity (μ_5) and of density (μ_3), may well be presumed to give indications of the comparative energies of condensed and of uncondensed æther. We may, therefore, hypothetically assume that

$$\mu_5 : \mu_3 :: \text{Projectile gaseous } \textit{vis viva} : \text{Æthereal } \textit{vis viva}.$$

The quotient of Sun's mass (μ_0) by Earth's mass (μ_3), which is indicated by the foregoing note, is 332,613. This gives, for the quotient of Jupiter's mass (μ_5) by μ_3, 317.416, and for the velocity of light, 186,538 miles. Substituting these values in the above proportion, and designating the densities of æther and of hydrogen by δ_a and δ_h, we get

$$\frac{317.416}{1} = \frac{\delta_h}{\delta_a} \times \left(\frac{1.235}{186538}\right)^2$$

$$\delta_h = 7{,}242{,}500{,}000{,}000\ \delta_a$$

This exceeds the ratio which was deduced from æthereal and gravitating interaction† by a little more than six per cent. But in that approximation the factor of terrestrial projection, $p = 1.06994$, was omitted. If we introduce this factor and increase our estimate of Earth's density about $\frac{7}{9}$ of

* Proc. Am. Phil. Soc., ix, 440; xii, 407.
† Ib., xix, 209.

one per cent., the accordance between the two independent approximations will be exact. If the æthereal density towards the centre of density varies inversely as the square of the distance from Sun, the ratio at Earth's orbital distance should be 333,230,000,000,000,000, representing about two and a half times the æthereal density which Sir William Thomson gives as his lowest estimate.

36. *The Experimentum Crucis.*

At the meeting of the American Philosophical Society in which Dr. Henry Draper announced his discovery of oxygen in the Sun, he proposed that I should test my theory of harmonic æthereal action by an examination of the solar spectrum. I accordingly sent a note to the Society, on the 23d of August, 1877,* in which I showed that the wave-lengths of five of the Fraunhofer lines were in harmonic progression, and that four of them were also figurately harmonic, viz:

Lines.	Wave-lengths.	Divisors.	Harmonic Quotients.
A	761.20	1.0000	761.20
B	687.49	$1.1071 = 1 + 7 \times .0153$	687.56
D_1	589.74	$1.2907 = 1 + 19 \times .0153$	589.76
F	486.52	$1.5661 = 1 + 37 \times .0153$	486.05
H_1	393.59	$1.9333 = 1 + 61 \times .0153$	393.73

The cosmical importance of these harmonies is shown by their relation to the projectile energies of Sun (μ_0) and Jupiter (μ_5), as measured by the product of their respective masses by their perihelion vector-radii. For $\frac{\mu_5 \rho_5 - \mu_0 \rho_0}{\mu_0 \rho_0} = .0153$.

I showed, moreover, that the combined photodynamic influence of the centres of nucleation and of nebulosity, μ_0 and μ_5, is traceable in the remaining Fraunhofer and other subordinate lines, viz:

Lines.	Wave-lengths.	Divisors.	Harmonic Quotients.
C	656.67	$1.1530 = 1 + 10 \times .0153$	660.19
	634.05	$1.1989 = 1 + 13 \times .0153$	634.92
	550.70	$1.3825 = 1 + 25 \times .0153$	550.60
E	527.38	$1.4437 = 1 + 29 \times .0153$	527.26
b	517.70	$1.4743 = 1 + 31 \times .0153$	516.31
	458.66	$1.6579 = 1 + 43 \times .0153$	459.13
G	431.03	$1.7650 = 1 + 50 \times .0153$	431.27

The influence of the pendulum-factor is shown in the tendency to differences among the harmonic divisors, which are multiples of $3 \times .0153$ or sub-multiples of $2^2 \times 3 \times .0153$.

37. *Supra-Telluric Æthereal and Cosmical Nodes.*

The crucial demonstration of the law of harmonic oscillation, in the æthereal medium as well as in the bodies which are whirling in its eddies,

* Proc. xvii, 109-12.

gave conclusive evidence of the importance, in all physical investigations, of studying elastic reaction as well as centripetal or centrifugal action. An important fact, in connection with such comparative study, is the variation of elastic density in inverse geometrical ratio, when distance varies in arithmetical ratio. We may, therefore, look for exponential harmonic relations between planetary positions, of a character analogous to the simple harmonic relations between wave lengths. Let k_a represent the kinetic projectile ratio of Neptune, Sun's semi-diameter being the unit; k_β, the mean projectile ratio of the nebular centre of planetary inertia; k_γ, the projectile ratio of the centre of spherical gyration of the centre of condensation; λ_a, λ_β, etc., the corresponding wave-lengths; t_χ, the ratio of orbital time; t_λ, the ratio of photodynamic time; v_λ, orbital velocity at the rupturing locus of mean planetary inertia; v_χ, orbital velocity at the subsidence locus of mean planetary inertia; n, the quotient of Earth's semi-axis major by Sun's semi-diameter. Then we have:

$$\log.\ k_a : \log.\ k_\beta :: \lambda_a : \lambda_\beta \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\log.\ k_a : \log.\ k_\gamma :: \lambda_a : \lambda_\gamma \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$\lambda_\beta : \lambda_\gamma :: 3^2 : 4^4 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$t_\chi : t_\lambda :: v_\lambda : v_\chi \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

These four proportions furnish data for estimating the four photodynamic values which are least known, by substituting the six which are best known. In equation (1), the estimates of k_a range between 30.034 n (Stockwell) and 30.070 n (Newcomb), the estimates of n varying from 214.3 to 214.9. As the uncertainty of n is the greater, I adopt it as one of the four unknown quantities, and use Leverrier's intermediate coefficient, 30.067. For λ_a I take the wave-length of the Fraunhofer line A, 7612 ten millionths of a millimeter. In equation (2), in the æthereal sphere of which the centre of condensation is the nucleus, the mean projection of spherical gyration is represented by .4 n, and the radius of solar reaction (k_γ) by .6 n. In equation (3), the numbers 3 and 4 are linear representatives of the exponential radii of synchronous nucleal and atmospheric nebular variation; 3^2 is the pendulum ratio of varying central force; 4^4 is the ratio of variation in the centripetal energy of nodal collisions in paraboloidal aggregation. In equation (4), $t_\chi = (30.037\ n)^{\frac{3}{2}}$; $t_\lambda =$ the solar modulus of light divided by Sun's semi-diameter $= \left(\frac{31558149}{2\ \pi\ n^{\frac{1}{2}} \times 497.827}\right)^2 = 101790260 \div n$; $v_\lambda \div v_\chi = \left(\frac{1+e}{1-e}\right)^{\frac{1}{2}}$, e being the maximum secular eccentricity of the planetary aggregation (Saturn) at the nebular centre of planetary inertia. Making these substitutions, we get,

$$\log.\ 30.037\ n : \log.\ k_\beta :: 7612 : \lambda_\beta \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)_1$$

$$\log.\ 30.037\ n : \log.\ .6\ n :: 7612 : \lambda_\gamma \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)_1$$

$$(30.037\ n)^{\frac{3}{2}} : 101790260 \div n :: (1+e)^{\frac{1}{2}} : (1-e)^{\frac{1}{2}} \ldots\ldots (4)_1$$

Solving the proportions, we find the following accordances :

Theoretical.	Observed.		Ratio of Difference.
n 214.45	214.45	Brit. Naut. Almanac.	0 of one per cent.
k_β 1.1862	1.1842	Stockwell,	$\frac{1}{6}$ " "
λ_β 148.20	148.18	Lockyer,	$\frac{1}{7\frac{1}{4}}$ " "
λ_γ 4215.55	4215.00	Lockyer,	$\frac{1}{7\frac{1}{4}}$ " "

$$(1+\epsilon)^{\frac{1}{2}} : (1-\epsilon)^{\frac{1}{2}} :: v_\lambda : v_\chi :: (1.0852)^{\frac{1}{2}} : (.9148)^{\frac{1}{2}} :: (1.1862)^{\frac{1}{2}} : 1 :: (k_\beta)^{\frac{1}{2}} : 1$$

$$k_a = 6441.4$$
$$k_\gamma = 128.67$$
$$\lambda_0 = 16.467$$

The same principles are further illustrated in the following comparative table :

Exponents and Divisors.		Harmonic Roots.	Observed.		Harmonic Quotients.	Observed.
1.0000		6441.4	6441.4	Neptune,	7612	7612 A.
1.05355 = 1 + $\frac{7}{2}$ × .0153		4125.1	4113.9	Uranus,	7225	7196 a.
1.1071	1 + 7 × .0153	2757.7	2742.6	" c. o.,	6876	6875 B.
1.1530	1 + 10 × .0153	2011.8	2045.6	Saturn,	6602	6567 C.
1.1989	1 + 13 × .0153	1503.5	1510.7	Geom. mean,	6349	6340
1.2448	1 + 16 × .0153	1148.0	1115.7	Jupiter,	6257	6236
1.2907	1 + 19 × .0153	893.6	892.6	$\frac{4}{5}$ "	5898	5897 D.
1.3366	1 + 22 × .0153	707.6	707.6	(167) (168)	5695	5687
1.3825	1 + 25 × .0153	569.1	569.2	(95)	5506	5507
1.4284	1 + 28 × .0153	464.1	457.2	(149)	5329	5274 E.
1.4743	1 + 31 × .0153	383.4	383.3		5163	5177 b.
1.5202	1 + 34 × .0153	320.3	326.8	Mars,	5007	5011
1.5661	1 + 37 × .0153	270.5	270.3		4860	4865 F.

The "exponents and divisors" are terms of an arithmetical progression, as was shown in the foregoing note, the common difference (.0153; Note 36) representing a differential action of Sun and Jupiter, the two controlling masses of the system. Therefore, all the roots which are obtained from 6441.4 by using the series as exponential denominators, are harmonic roots, and all the quotients which are obtained from 7612, by using the series as divisors, are harmonic quotients. The "observed" roots represent the mean planetary distances, if $n = 214.45$; the "observed" wave-lengths are given by Gibbs, in the American Journal of Science,* except a, which is interpolated from Angstrom's table. It is, therefore, evident that the external planetary positions and the most prominent spectral lines are both influenced by the same harmonic oscillations in the æther, modified by the law of density in the planetary nodes, and by the law of simple distance in the excursions of wave-lengths.

Harmonic influence is also shown in the roots which correspond to Uranus's linear centre of oscillation, the geometrical mean between the

* [2] xlIII, 4.

centres of nebulosity and of nebular planetary inertia, $\frac{4}{5}$ of Jupiter, the mean distance of asteroids 167 and 168, asteroid 85 and asteroid 149. The four roots between 893.6 and 464.1 are all asteroidal, the centre of asteroidal density being represented by 569.1. Newcomb gives the mean distances of 172 asteroids, of which 104 are at mean distances ranging between 506 and 594. The curve of frequency has a maximum at 566; the mean distance of the four chief asteroids in point of magnitude, Ceres, Juno, Pallas and Vesta, is 567; the mean distance of the five which include the maximum and are limited by equal ordinates of frequency, is 569.1. The mean distance of Mars is an arithmetical mean between 383.3 and 270.3, which correspond very nearly with the secular apsides.

38. *Nodes in the Dense Belt.*

In my harmonic anticipation of intra-Mercurial planets,* I showed that the controlling influence of Jupiter is modified by the nodal influences at the centre of the dense belt. This modification is also shown, and perhaps more strikingly, in the relations between the æthereal and cosmical nodes within the belt. If we begin with Mars, at the outer limit of the dense belt, and take successive increments of $\frac{1}{2}^5 \times .0153$, we find the following accordances:

Exponents and Divisors.		Harmonic Roots.	Observed.		Harmonic Quotients.	Observed.
$1.5202 =$	$1 + \frac{6}{2}^8 \times .0153$	320.3	326.8	Mars,	5007	5011
1.6350	$1 + \frac{8}{2}^3 \times .0153$	213.6	214.4	Earth,	4656	4671
1.7497	$1 + \frac{9}{2}^8 \times .0153$	150.3	149.7	Venus, m. p.,	4350	4310 G.
1.8644	$1 + \frac{11}{2}^3 \times .0153$	110.4	110.7	" l. c. o.,	4083	3972 H.
1.9792	$1 + \frac{12}{2}^8 \times .0153$	84.0	83.0	Mercury,	3846	
2.0939	$1 + \frac{14}{2}^3 \times .0153$	65.9	65.9	" p.,	3635	
2.2087	$1 + \frac{15}{2}^8 \times .0153$	53.0	55.3	" l. c. o.,	3446	

The infra-Telluric loci which represent the harmonic roots are Venus's mean perihelion; Venus's linear centre of oscillation of incipient subsidence, or of secular aphelion; Mercury, semi-axis major; Mercury, perihelion; Mercury, linear centre of oscillation. All of the harmonic roots, both supra-asteroidal and infra-asteroidal, correspond *precisely* with planetary loci, and *very nearly* with apsidal or mean positions. All the harmonic quotients represent regions of spectral interference, and correspond very nearly with the mean positions of important spectral lines. The numerous evidences which have been adduced of the influence of planetary disturbances upon Sun spots, together with Lockyer's explanation of the spots by "the approach or retreat of vapor," seem to justify a careful and systematic study of the variations in the position and breadth of spectral lines, such as I recommended in my note of August 23, 1877.† By observations at different hours of the day, it would soon be found whether there is any systematic daily variation; three months would suffice for approxi-

*Proc. Am. Phil. Soc., xiii, 237-9.
†Ib. xvii, 112.

mately estimating the disturbing influence of Mercury; and in a year all the planetary regions of the spectrum might be studied. The relations of the C line to Saturn and to hydrogen may, perhaps, be found specially interesting.

39. *"Basic Lines."*

The values of λ_0 and λ_γ (Note 37) serve to connect Lockyer's basic-lines with æthereal and cosmical nodes.

Harmonics.	Basic Lines.
$4^4 \times \lambda_0 = 4215.6$	4215
$(4^4 + 7^2) \times \lambda_0 = 5022.4$	5017
$(4^4 + 7^2 + 3^2) \times \lambda_0 = 5170.6$	5170
$(4^4 + 7^2 + 3^2 + 2^2) \times \lambda_0 = 5236.5$	5235
$(4^4 + 8^2) \times \lambda_0 = 5269.4$	5269
$(4^4 + 8^2 + 3^2) \times \lambda_0 = 5417.6$	5416
$4^2 \times 5^2 \times \lambda_0 = 6586.8$	6567

The third and fifth "basic lines" are double. Lockyer gives for the third, b_3, b_4; for the fifth, 5268, 5269. Gibbs gives 5177 for the length of the b line; Angstrom's table gives 5167, 5164, for b_3, b_4. The mean, according to Gibbs' measurements, is 5170. The three hydrogen lines, α, β, γ, correspond nearly with the Fraunhofer lines, C, F, and G, but Angstrom makes the wave-length of the γ line 4340. The three lines may be expressed by $4^2 \times 5^2 \times \lambda_0 = 6586.8$; $(4^4 + 5 \times 2^3) \times \lambda_0 = 4873.7$; $(4^4 + 2^3) \times \lambda_0 = 4346.7$.

40. *Chemical Spectra.*

Soon after my announcement of the accordance between the simple harmonic wave-lengths in the solar spectrum and the exponential harmonic loci in the solar system, I showed * that the law of harmonic vibration also extends to the spectra of chemical elements. The following accordances are especially interesting in relation to the basic lines:

	Normal Differences.	Observed.	
Hg.,	$5428.0 + 2\lambda_0 = 5460.9$	5428.0	5461.3
Pb.,	$4390.7 + 6\lambda_0 = 5378.7$	4390.7	5377.1
Li.,	$4599.3 + 12\lambda_0 = 4796.9$	4599.3	4794.8
Rh., Ir.	$5305.2 + 9\lambda_0 = 5453.6$	5305.2	5454.4
Cu.,	$5292.7 + 30\lambda_0 = 5786.7$	5293.0	5786.7
As.,	$5335.5 + 51\lambda_0 = 6174.7$	5335.5	6175.4
	$5787.3 + 20\lambda_0 = 6116.6$	5787.3	6116.7
Zn.,	$4723.2 + 84\lambda_0 = 6106.4$	4722.5	6106.4
	$6106.4 + 16\lambda_0 = 6369.9$	6106.4	6369.9

The tendency to composite and pendulum multiples of the fundamental line is also shown here; 2, 2×3, $2^2 \times 3$, 3^2, $2 \times 3 \times 5$, $3 \times (2^4 + 1)$, $2^2 \times 5$, $2^2 \times 3 \times 7$, 2^4. The Arsenic line, 5335.5, is $2^2 \times 3^4 \times \lambda_0$; in the two

* Ib. xvii, 297–301.

copper lines which precede the two which I have given, the differences are $\frac{1}{7}$ of 30 λ_0 and $\frac{3}{7}$ of 30 λ_0.

41. *The Corona Line.*

In the communication* which led to my spectroscopic investigations, Dr. Draper anticipated the probability of finding a key to "the 1474 K or corona line." The following accordances may help towards a solution of the mystery. The numbers in the right-hand column are the measurements by Gibbs:

Geometric Wave-lengths.	Observed Wave-lengths.	
$4311.9 \times 1.0305^{14} = 6567.8$	C	6566.7
$4311.9 \times 1.0305^{7} = 5321.7$	1474 K	5322.0
$4311.9 \times 1.0305^{4} = 4862.8$	F	4865.2
$4311.9 \times 1.0305^{0} = 4311.9$	G	4310.3

I have shown† that the harmonic densities of C and G are photodynamically represented by the loci of Saturn and Venus. The corona line is a mean proportional between C and G. The exponential ratio of $\frac{F}{G}$ to $\frac{C}{F}$ is the same as the ratio of the mean moment of inertia of spherical rotation to the moment of superficial equatorial rotation. The ratio of $\frac{1474\ K}{F}$ to $\frac{F}{G}$ is the same as the ratio of variation in an expanding or contracting nucleal radius to the atmospheric radius.

42. *The Hydrogen Lines.*

Lockyer gives four hydrogen lines, C, F, γ, h. The corresponding geometric wave-lengths give the equations, $Fh^2 = \gamma^3$; $F^{11} = C^4h^7$.

Geometric Wave-lengths.	Angstrom's Wave-lengths.	
$4099.5 \times 1.01435^{33} = 6560.2$	C	6561.8
$4099.5 \times 1.01435^{12} = 4863.9$	F	4860.6
$4099.5 \times 1.01435^{4} = 4339.9$	γ	4340.
$4099.5 \times 1.01435^{0} = 4099.5$	h	4101.2

The most prominent line in the hydrogen spectrum, and the only one in some cases, is F, which, as I have shown, is geometrically connected with the corona line and with important cosmical nodes.

43. *Three Orders of Spectra.*

The two foregoing notes introduce a new order of spectra which seems to be of a more elementary character than either of the two which I have previously considered. The geometrical progression of wave-lengths suggests a repetition of impulse, while the absence of some of the terms of the progression indicates a want of complete homogeneity.

The second order is that of the basic lines, which consists of a combina-

* Proc. Am. Phil. Soc., xvii, 77.
† Ib., xvii, 109–12.

tion of arithmetical repetitions of a fundamental wave-length, which is harmonically related to cosmical nodes.

The third order is the one which first attracted my attention,* consisting of groups of wave-lengths which are in harmonic instead of geometric progression, and indicating, like the first order, a want of complete homogeneity.

These three orders are variously blended in the spectra of so-called chemical elements. The character of the blending may, perhaps, serve as a guide towards the resolution of the spectra into simpler constituents.

44. *Æther, Corona, Hydrogen.*

In a communication to the Society, on the 18th of December, 1863, I showed that there is some elastic influence between Sun and Earth, which enables us to form approximate estimates of Sun's mass and distance. At the close of the communication was the following paragraph.†

"The revolution of the Sun around the great Central Sun must also cause barometric fluctuations that may possibly be measured by delicate instruments and long and patient observations. The Torricellian column may thus become a valuable auxiliary in verifying or rectifying our estimates of the distances and masses of the principal heavenly bodies."

In various subsequent communications I have shown that electricity, magnetism, solar gravitation and rotation, planetary and stellar positions, spectral lines, chemical affinity, thermal energy, and other physical manifestations,‡ furnish marked indications of an all-pervading elastic medium, vibrating with the velocity of light, and subject to the same laws of harmonic nodal action as have been found to influence the air and other elastic bodies.

The observations upon the solar eclipse of 1869, by Morton, Winlock Young, Pickering, Harkness and others, disclosed an important line in the solar spectrum, which corresponds very nearly to 1474 of Kirchhoff's scale, and is now styled 1474 K, or "the corona line." Father Secchi attributed the line to hydrogen; Dr. Gould thought it identical with the auroral line, and therefore due to some substance which, as stated by Lockyer,§ "may possibly be present in the higher regions of our own atmosphere."

Lockyer‖ considers the observations as indicating "an enormous envelope of hydrogen, probably in the average twelve minutes high," as well as "the existence of some unknown element extending further from the photosphere even than hydrogen." In the eclipse of 1870, "at the same time that this line was observed to extend to a distance of 20′ from the Sun, the lines of hydrogen were observed eight minutes above the Sun." Here are, therefore, probable evidences of two successive stages of æthereal condensation. It has "been shown by Salet, Schuster and others, that" all the hy-

* Ib., xvii, 109-12, 297-301.

†Ante, ix., 288; Phil. Mag. [4], xxviii, 59.

‡Ante, ix, xiv; xvi, sqq.; P. Mag. [4], vols. 30, 32, 34, 35, 50; [5], 1-6, 10, 11.

§Solar Physics, p. 269.

‖ Ib. p. 413.

drogen lines but F are "due to impurities," * so that the hydrogen spectrum is harmonically connected with the corona line.

It may be well to recapitulate, in this connection, some of the simple equations which serve to connect the energies of solar and terrestrial rotation, planetary revolution, atmospheric limitation, molecular oscillation, cosmical aggregation, and æthereal action:

1. $M : \pi r :: v_\lambda : v_r$ Note 34.
2. $v_r = p\, v_h$ Note 34.
3. $v_\lambda = \left(\frac{gt}{2}\right)_0$ Notes 33, 37.
4. $v_0 = p \left(\frac{gt}{2}\right)_2$ Note 17.

See, also, Proc. Am. Phil. Soc., xii, 392–4; xix, 21–5, and Note 16.

45. *Cosmical Significance of the Corona Line.*

Earth being the centre of density in the solar system, its nascent locus should have a time of revolution π times as great as its own, with a semi-axis major of $\pi^{\frac{2}{3}} \times 214.45 = 460.002$ solar semi-diameters. The corresponding wave-length (Note 37,) is 5321.35, as is shown by the following proportion:

log. 6441.4 : log. 460.002 : : 7612 : 5321.35.

This differs by less than $\frac{1}{152}$ of one per cent. from the geometric wave-length (Note 41), and by less than $\frac{1}{80}$ of one per cent. from Gibbs's measurement of the corona line.

The Systematic Arrangement of the Order Perissodactyla. By E. D. Cope.

(*Read before the American Philosophical Society, April* 15, 1881.)

PERISSODACTYLA.

This, the second great order of the ungulate Mammalia, naturally occupies a position between the *Amblypoda* and the *Artiodactyla*. Its lower forms are more specialized in the structure of the feet than the *Amblypoda*, while its highest types do not reach the perfection of structure seen in the *Artiodactyla*. This is particularly indicated by the form of the astragalus, which has but one, the tibial trochlea, and never displays the distal one characteristic of the cloven-footed families. The *Perissodactyla* occupy, as regards their dentition, a position parallel with the *Artiodactyla*. They are always superior in dental complication to the *Proboscidia* and the suiline *Artiodactyla*, but only one series, that of the horses, reaches the com-

* Ib. p. 530, foot-note.

plexity of molars general in the *Ruminantia*. The dentition of the mass of the *Perissodactyla* might be described as intermediate between that of the *Proboscidia* and the lowest selenodont *Artiodactyla*.

The families of this order form a closely connected series, and the division of them into three divisions, the "Pachydermata," "Solipeda" and *Perissodactyla*, has no warrant in nature. Especially unnatural is the conjunction of the genera included under the first name, with the *Proboscidia* and certain suilline *Artiodactyla*, in a single order, as was proposed by Cuvier. The modifications of dentition from the simple type seen in *Menodus*, to the most complex, as in *Equus*, are close and consecutive. So, also, the gradual diminution in the number of digits from 5–4 to 1–1 can be traced through all the intervening stages.

The following definitions of families are applicable in the present stage of knowledge. Those of all but three were published in the Bulletin of the U. S. Geological Survey of the Territories, 1879, p. 228. A modification in the diagnoses of the families *Chalicotheriidæ* and *Palæotheriidæ* is now introduced:

I. Anterior exterior crescent of superior molars shortened, not distinguished from the posterior by external ridge; inferior molars with cross-crests; premolars different from molars.

1. Toes 4–3 ..... *Lophiodontidæ*.
2. Toes 3–3 ..... *Triplopodidæ*.

II. Exterior crescents of superior molars as in I; inferior molars with cross-crests; superior molars and premolars alike, with cross-crests.

3. Mastoid bone forming part of the external wall of the skull ..... *Hyracodontidæ*.
4. Mastoid bone excluded from the walls of the skull by the contact of the occipital and squamosal ..... *Rhinoceridæ*.

III. Exterior crescentoid crests of superior molars subequal, distinct; inferior molars with cross-crests.

5. Superior molars and premolars alike and with cross-crests; toes 4–3... *Tapiridæ*.

IV. The external crescentoid crests of the superior molars subequal, separated by an external ridge; inferior molars with crescents.

A. Superior premolars different from molars; with only one internal cusp.

6. Toes 4-3; a vertebrarterial canal ..... *Chalicotheriidæ*.
7. Toes 3–3; no vertebrarterial canal ..... *Macraucheniidæ*.

AA. Premolars like molars, with two internal lobes above.

8. Toes with digits, 4–3 ..... *Menodontidæ*.
9. Toes with digits, 3–3 ..... *Palæotheriidæ*.
10. Toes with digits, 1–1 ..... *Equidæ*.

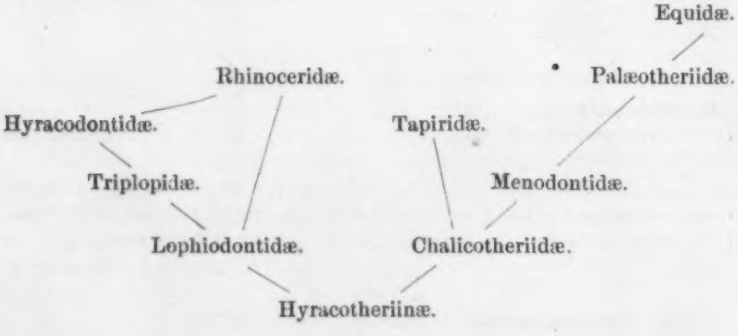
The genera included in these families are the following. The table shows their geological distribution :

	EOCENE.		MIOCENE.			PLIOCENE.	RECENT.
	Lower	Upper	Lower	Middle	Upper		
Lophiodontidæ.							
Hyracotherium Ow.	12						
Pliolophus Ow.	4	2					
? Lophiotherium Gerv.		1					
Pachynolophus Pom.	3	3					
Helaletes Marsh.		3					
Lophiodon Cuv.	2	11					
Hyrachyus Leidy.		9					
Colonoceras Marsh.		1					
Triplopidæ.							
Triplopus Cope.		2					
Hyracodontidæ.							
Hyracodon Leidy.			2				
Rhinocerontidæ.							
Aceratherium Kaup.			3				
Cœnopus Cope.			2				
Diceratherium Marsh.				3			
Zalabis Cope.							
Aphelops Cope.					4		
Ceratorhinus Gray.				1	2		2
Rhinocerus Linn.					4		2
Peraceras Cope.					2		
Atelodus Pom.					2	1	2
Cœlodonta Bronn.						3	
Tapiridæ.							
Listriodon Gerv.				? 3			
Tapirus Linn.						6	5
Elasmognathus Gill.							1
Chalicotheriidæ.							
Rhagatherium Pict.	1						
Leurocephalus S. S. and O.		1					
Palæosyops Leidy.	1	5					
Limnohyus Leidy.		3					
Lambdotherium Cope.	2	1					
Propalæotherium Gerv.	1	2					
Chalicotherium Kaup.		3					
Nestoritherium Kaup.				? 1			
Meniscotherium Cope.	1						
Macrauchenidæ.							
Macrauchenia Ow.					2		

	EOCENE.		MIOCENE.			PLIOCENE.	RECENT.
	Lower	Upper	Lower	Middle	Upper		
Menodontidæ.							
Acoëssus Cope	1						
Diplacodon Marsh		1					
Menodus Pom			2				
Symborodon Cope			6				
Dæodon Cope				1			
Palæotheriidæ.							
Anchilophus Gerv		2					
Paloplotherium Ow		6					
Palæotherium Cuv		3					
Mesohippus Marsh			2				
Anchitherium Kaup			2	4			
Anchippus Leidy				1	1		
Hippotherium Kaup					8	1	
Protohippus Leidy					5	1	
Equidæ.							
Hippidium Owen					2	3	
Equus Linn						5	7

Total number of well determined species, one hundred and eighty-nine.

From the preceding table it can be readily seen that this order was abundantly represented during the Eocene period, and that the recent species are comparatively few. It may also be observed that certain families predominated during certain periods. Thus the prevalent *Perissodactyla* of the Eocene are *Lophiodontidæ* and *Chalicotheriidæ;* those of the Miocene are *Rhinocerontidæ* and *Palæotheriidæ*. The *Tapiridæ* and *Equidæ* characterize the latest tertiary epochs. A genealogical tree of the order may be constructed as follows :



The types of the *Lophiodontidæ* and *Chalicotheriidæ* differ only in the two

points of the separation, or non-separation, of the exterior crescents of the superior molars, as already pointed out. That no great modification of known forms (as *Lambdotherium* in the *Chalicotheriidæ*, and *Hyracotherium* in the *Lophiodontidæ*) would be necessary to obliterate this difference, is quite clear. The parent types of the order, which present the most generalized dentition, *Hyracotherium*, *Rhagatherium*, and *Acoëssus*, were cotemporaries of the Lower Eocene epoch.

LOPHIODONTIDÆ.

This family embraces a larger number of known species than any of the others of the order. With one exception, all the species belong to the Eocene period. They range from the size of a rabbit to that of an ox. They resembled most, among living animals, the tapirs.

The genera are characterized as follows :—

I. External lobes of superior molars well separated and little flattened; lobes of inferior molars scarcely united (*Hyracotheriinæ*).

A. No diastema behind first premolar.

a. Third and fourth inferior premolar like the first true molar.

Last inferior molar with five lobes ..... *Lophiotherium*.

AA. A diastema behind the first premolar in both jaws.

a. Last inferior premolar different from first true molar;

Last inferior molar with heel; cross-crests of superior molars interrupted; *Hyracotherium*.

aa. Last inferior premolar like first true molar;

True molars as in *Hyracotherium* ..... *Pliolophus*.

II. External lobes of superior molars flat, not well distinguished. (*Lophiodontinæ*.)

"*A*. No diastema in lower jaw.

Last inferior molar with third lobe ..... *Helaletes*."

AA. Lower jaw with diastema.

*No diastema behind first premolar.

a. No inferior premolars like the true molars.

Superior molars 7.

Last inferior molar with heel ..... *Pachynolophus*.

Superior molars 6;

Last inferior molar with heel ..... *Lophiodon*.

Last lower molar without heels, no horns ..... *Hyrachyus*.

Last lower molar?; "an attachment for a dermal horn on each nasal bone" ..... *Colonoceras*.

The geographical range of these genera is as follows :—

North America only ..... *Helaletes, Colonoceras*.

North America and Europe; *Pachynolophus, Hyrachyus, Hyracotherium, Pliolophus.*

Europe only; *Lophiodon, Lophiotherium.*

Four of the genera ascribed to North America have come under my observation.

TRIPLOPIDÆ.

Cope, American Naturalist, 1881, April (March 25th), p. 340.

But one genus of this family is known at present, but the number will probably be increased when the structure of the feet of various imperfectly known species is ascertained.

Fig. 1. Part of right maxillary bone of *Pachynolophus singularis* Cope; from the Wasatch beds of New Mexico, from Capt. Wheeler's report iv ii pl. lxvi.

TRIPLOPUS Cope.

American Naturalist, 1880, p. 383 (April 27th).

Dental formula, I. ?; C. $\frac{1}{1}$; P-m. ; $\frac{4}{4}$; M. $\frac{3}{3}$; a considerable diastema anterior to the first premolar. Molars with only two vertical external ridges, the anterior cingular and the approximated median of the anterior crescent. Transverse crests two, uninterrupted and rather oblique; a ? third and short crest, on the posterior base of the first true molar. Premolars different from molars, the third and fourth with two transverse crests. Inferior molars with two transverse crests, as in *Lophiodon*, the last without heel.

An ossified inferior wall of the meatus auditorius externus. Posttympanic and paroccipital processes distinct form each other. No postorbital arch. Postparietal and mastoid foramina preserved; the latter large. Cervical vertebræ rather long; axis with subcylindric odontoid process. Scapula with small coronoid process. Great tuberosity of humerus long, curved. No trochlear crest on condyles of humerus; epicondyles rudimental. Ulna and radius distinct throughout their length; ulnar articulation with carpus, small. Trapezoid bone of carpus with a facet for the trapezium. Unciform with two inferior facets. Metacarpals three principal ones, and one, the fifth, rudimental; the distal extremities of the second and fifth opposite; the third a little longer.

The dentition of this genus is nearly that of *Hyrachyus*. The only exception is the possible third transverse crest of the first true molars*. The other portions of the skeleton known, are also much like those of *Hyrachyus*, with the exception of the number of digits of the anterior foot. The entirely rudimental character of the fifth metacarpal, which with its

*This point is further considered in the description of the species.

digit, is so well developed in *Hyrachyus*, places *Triplopus* in another family, and in another line of descent. I think that it must be regarded as one of the forms of the series connecting the tapirs with the rhinoceroses. The fourth digit (the fifth) was retained by the earliest type of rhinoceros in Europe, the genus *Aceratherium*, but in America it appears to have been lost earlier. None of the American rhinoceroses of the Lower Miocene of the genus *Cœnopus* Cope present it, and in the present genus we have an ancestral type of the Eocene period, in which the last digit is already lost. The premolars of different structure from the true molars, exclude this genus from the *Rhinocerontidæ*, and with the character of the feet place it between that family and the *Lophiodontidæ*.

As yet, but one species of *Triplopus* is certainly known, but a second is placed in it provisionally.

TRIPLOPUS CUBITALIS Cope.

American Naturalist, 1880, p. 383.

This species is represented by a nearly entire skull with lower jaw; most of the cervical vertebræ; a left anterior limb nearly complete; a part of the left scapula, and a part of the right anterior limb; all belonging to one animal. The specimen was not quite adult, as the last superior molar is just protruding its crown through the maxillary wall, and the last two superior milk premolars still remain in place, much worn and closely pressed by the overlying successional teeth.

The *cranium* is peculiar in its wide orbital region, and short compressed muzzle; the latter is damaged in the specimen so that the form of the nasal bones cannot be determined, except at their proximal portions. The interorbital space is plane in both directions, and rises very gently posteriorly. The sagittal crest is narrow and low, until above the meatus auditorius, where it rises. Above the posttympanic process it bifurcates, and each rounded lateral lobe extends posteriorly to a point above the occipital condyles. Viewed from above the head is wide between the zygomatic fossæ, and at the posterior premaxillary teeth. The top of the muzzle narrows rapidly above the latter, but does not contract below until the first premolar is reached. The zygomatic arch is not convex along its middle, and encloses a narrow fossa. The superciliary border is prominent, and nearly straight, and is bounded by a notch behind. The squamoso-occipital ridge is well marked. The posttympanic process is shorter than the paroccipital, and is separated from it by an open shallow groove, which is probably bottomed by the mastoid bone. The paroccipital process is much narrowed below and is turned a little outwards. There are two closely adjacent tubercles on the anterior border of the orbit, probably on the lachrymal bone.

Foramina. Only a few of these are well preserved; among the lost is the *f. infraorbitale*. There are two postparietal foramina on one side, and one on the other, above the point of origin of the zygomatic process of the squamosal bone; and one in the usual posterior position. The post-squamosal has the same anterior position as the anterior postparietals,

being immediately below them; I cannot discover whether there is a posterior one or not owing to injuries to the specimen. There is apparently a fissure-like one on the parieto-squamosal suture posteriorly. The mastoid is quite large, expanding downwards and outwards; it is not so large as in a tapir, but much exceeds that in *Hyrachyus eximius*. The *meatus auditorius externus* is large, and occupies only the posterior part of the space between the postglenoid and posttympanic processes. It is enclosed anteriorly and below by the border of a wide element which may be tympanic. It encloses the petrous bone below in a bulla; as however the inner portion of the best preserved one is broken away, I cannot speak of its relations to the basioccipital bone. The *foramen lacerum posterius* is reduced to a jugular and perhaps another connected foramen by the close apposition of the petrous bone to the basioccipital for a considerable distance. The region of the *f. l. medius* is injured. Posterior to the *f. l. posterius* is a foramen opposite the base of the paroccipital process, anterior to the usual position of the *f. condyloideum*.

Mandible. The angle of the lower jaw is produced posteriorly, as in some species of *Hyrachyus:* cfr. figs. Vol. IV, U. S. Geol. Surv. Terrs. The coronoid process is long and is curved backwards to above the posterior border of the condyle. There is no tuberosity behind the condyle. The symphysis is quite contracted and is short. The mental foramen is below the middle of the inferior diastema. The ramus is compressed and at the same time strong.

Dentition. As the deciduous third and fourth premolar teeth, in a worn condition, remained in the maxillary bone, I removed them from one side, thus displaying the crowns of the corresponding permanent teeth. The first premolar may belong to the permanent dentition; the second is the deciduous. The former has two roots. The crown is cutting for a short distance anteriorly, but posteriorly it expands into a heel, much less developed than the internal lobe of the succeeding teeth. The crowns of the third and fourth premolars differ externally, as well as in their crests, from those of the true molars. The median-anterior and cingular vertical ridges are not so prominent as in the latter. The external crest is not divided into two by the notch in its grinding face. The anterior cross-crest, at its inner or distal extremity, is turned shortly backwards and then inwards, giving a "pot-hook" outline to its triturating surface. The fourth deciduous premolar presents a peculiar character already ascribed to the first true molar. This consists of a crest running parallel with the posterior transverse crest and close to it, along its posterior side. It forms the border of the tooth for a short distance, but as its direction is slightly obliquely forwards as well as outwards, the posterior cingulum appears for a very short distance.

The first true molar is subquadrate in outline. The anterior transverse crest commences at the middle anterior ridge, and is first transverse, then directed a little obliquely backwards. The second crest commences at the apex of the posterior external crescent, leaving a wide posterior marginal

fossa. Its internal extremity is broken off. Posterior to, and in contact with it, the posterior cingulum rises in a crest, which occupies the internal half only of the border. Its inner border is imperfect. It appears to me to be probable that the normal posterior crest is turned posteriorly on itself so as to give the "pot hook" shape seen in the anterior crest of the fourth permanent premolar. The corresponding accessory crest in the fourth temporary premolar appears to have been distinct at its internal extremity. The second true molar has a more oblique posterior external crest, and the posterior internal is oblique and simple. It has narrow anterior and posterior basal cingula. There is no tubercle between the inner bases of the transverse crests of this or the last true molar. The latter is characterized by the rudimental character of the posterior external crescent crest, which is shortened like that of *Hyrachyus*. The transverse crests are curved backwards; the posterior is short and simple.

The canines are small, and are directed forwards. The extremity of the muzzle being broken, the relation of the incisors cannot be stated, but there was not probably any precanine diastema. An incisor preserved has the crown transversely expanded, and rather oblique.

The third and fourth inferior premolars are the deciduous ones, and are both three-lobed, but differ in the forms of the anterior lobe. In the third, it is narrow and incurved, as in the corresponding permanent teeth of some *Artiodactyla*. The transverse crests of the true molars are rather oblique, running forwards as well as outwards.

Their external extremities are bent at right angles, and there results a short descending crest running forwards and inwards; the anterior one turns inwards, again forming a transverse anterior ledge. No cingula on internal or external bases of crown; a rudimental posterior one.

Measurements of Cranium.	M.
Length from front of canine tooth to end of occipital condyles	.128
Length from same to postglenoid process	.096
" " " to end of last molar	.069
" " " to first premolar	.015
" " " to line of front of orbit	.044
Width between superciliary borders	.046
" of zygomata at orbits	.064
" of brain-case at glenoid surface	.048
" of occipital condyles	.023
" of basioccipital bone between *ossa petrosa*	.006
Distance between postglenoid and posttympanic processes	.014
Depth of occiput behind	.033
" of mandible from condyle	.040
" of mandibular ramus at third premolar	.014
" at diastema (axial)	.009
Least width of symphysis	.011

Measurements of Cranium.	M.
Diameter crown third permanent premolar { anteroposterior...	.007
Diameter crown third permanent premolar { transverse.	.005
Anteroposterior diameter crown first premolar.....	.0045
Diameters crown first true molar { anteroposterior.....	.010
Diameters crown first true molar { transverse	.012
Diameters crown second inferior true molar { anteroposterior	.011
Diameters crown second inferior true molar { transverse.	.0075
Diameter of root of inferior canine near crown.....	.0035

Vertebræ. The atlas is about as long relatively as that of the horse. Its transverse processes have more anteroposterior than transverse extent. The summit of the neural arch has a median ridge separating two grooves. The inferior surface of the centrum has a nearly median, obtuse hypapophysis. The axial facets are well separated below. The vertebrarterial canal pierces the base of the transverse process behind and below, and notches it deeply anteriorly. Above this notch the usual perforation of the arch is present. The axis is not relatively quite so long as that of the horse; it is a little longer than in *Hyrachyus eximius*, but rather shorter than in *Hyracodon arcidens* (Pl. CII, Fig. 7). The atlantal facets are spread well apart, and the articulating surface of the odontoid does not connect with them. The latter is rather long, is obtuse, and slightly recurved; it has no raised borders. Between the atlantal faces the inferior surface is plane. Posterior to this the middle line bears a prominent keel. The diapophyses are long, narrow and recurved, and each is pierced at the base by the vertebrarterial canal. The posterior articular face is but little concave, and a little oblique, and is a little wider than long.

The succeeding cervicals regularly diminish in length, and become more strongly opisthocœlous, the seventh having quite a ball in front. The sixth has a slender diapophysis directed posteriorly, and quite distinct from the wide and long parapophysis which is directed downwards and outwards. The posterior angle of the latter extends as far back as the centrum. The seventh has only a flat transverse diapophysis. The first dorsal has a very stout diapophysis excavated below for the rib tubercle. The diapophyses of the third and fourth dorsals are not so stout. The capitular fossæ are large. The centra of the anterior dorsals are flattened below; they are concealed in part by the matrix in this specimen. The neural spine of the sixth cervical is narrow, and is directed forwards. That of the seventh is vertical, and narrows rapidly from a base which is rather wide anteroposteriorly. The spines of the dorsals are wider, and are directed gently posteriorly; they are probably long, judging from the size of their bases.

Measurements of Vertebræ.	M.
Length centrum of atlas on side.....	.027
" " " below.....	.010
Width " " " posteriorly	.030

Measurements of Vertebræ.	M.
Width transverse process of atlas	.010
Vertical diameter neural and odontoid canal	.015
Length axis to odontoid process	.033
" odontoid process	.007
Diam. centrum behind vertical with hypapophysis	.012
Diam. centrum behind vertical without "	.009
Diam. centrum behind transverse	.0115
Length of centrum of fifth cervical	.030
" " seventh	.017
" " second dorsal	.014
Anteroposterior diameter of base of neural spine of second dorsal	.010
Expanse of head and tubercle of first rib	.012

Fore Limb.—The greater part of the blade of the scapula is lost. The neck is stout, and the coracoid is a short aliform process. The humerus is moderately robust, most so proximally. The greater tuberosity is a strongly incurved crest, with truncate summit, which is a little elevated above the plane of the head, from which it rises rather abruptly. The bicipital ridges are not strong nor prominent. The olecranar fossa is deeper than the coronoid fossa, and they communicate by perforation. The inner part of the condyle is the largest, and forms an acute angle with the interior epicondylar surface. The exterior part of the condyle is divided by an oblique angle of the surface separating an external bevelled band of the same, which narrows to extinction on the posterior side. As compared with the humerus of *Hyrachyus eximius*, that of *Triplopus cubitalis* is very similar, differing mainly in two points at the distal extremity. The olecranar fossa is smaller and is less excavated, and its lateral bounding ridges are of unequal elevation; in *T. cubitalis* they are equal.

The ulna and radius are more than one-fourth longer than those of *H. eximius*. Although they are entirely distinct throughout, the ulna is quite slender anterior to the proximal third. The shaft is much more slender than that of *Hyrachyus eximius*. The olecranon is compressed, deep, and truncate behind. The distal epiphysis is remarkable for its length, being twice as long as that of the radius. The head of the radius is subequally divided by fossæ, the external being the shallower. The inferior or ulnar facet is regularly and gently convex downwards, and is bounded behind by a roughened ridge, which, near the external border turns backwards to the humeral border. The shaft of the radius is robust and flattened. The carpal facet of the radius is contracted, and has three times the superficial area of that of the ulna. The scapholunar dividing ridge is present, but is very low. The scaphoid face is the more excavated, and then rolls backwards, forming a very narrow posterior facet, which is narrower than that found in the species of *Anchitherium*. There is no distinct fossa on its inner or posterior border, as in many ungulates. The trapezium and scaphoid are the only bones of the carpus which are wanting. The latter

is probably wider than long or deep, while both the lunar and cuneiform are longer than wide. The cuneiform has not its external border excavated; its proximal surface is oblique and continuous, the ulnar and pisiform facets being in line. The pisiform is large, and is enlarged distally; its proximal facets are equal. The exposed face of the trapezoides is rather larger than that of the magnum, and is nearly as large as its own face of contact with the latter. The magnum has the usual great antero-posterior extension, with elevated posterior convexity applied to the fossa of the lunar. Its posterior process is long, nearly equal to the rest of the bone, and is depressed and flattened distally. The metacarpal facet is very concave. The unciform's anterior or exposed face is a little longer than wide. Its two proximal facets are about equal. It is about as deep as wide, and extends half its length distad to the magnum. Its posterior process is rather narrow; it is narrow and abruptly decurved. Distally, the facet for the fifth metacarpal is well marked, and has about half the area of that for the fourth metacarpal. The functional metacarpals are of moderate length as compared with the elongation of the ulnoradius. The third is largely in contact proximally with the unciform as well as with the magnum. The condyles are stout, and each is laterally impressed by a fossa. The second and fourth have chiefly lateral presentation, but are not much narrower in the shaft than the median metacarpal. The first phalange of the lateral digit is a little shorter than that of the median, while the seconds are of equal length. The extremity of the second digit reaches the proximal third of the length of the median ungual phalange. The fissure of the ungual phalange reaches the middle of its length. The fifth metatarsal is proximally rather stout; but it soon contracts to a thin rounded extremity, at only one-fifth the length of the fourth.

Measurements of Fore Limb.	M.
Antero-posterior diameter of cotyloid cavity of scapula	.015
Diameter of head of humerus { transverse	.020
Diameter of head of humerus { anteroposterior	.019
" with greater tuberosity	.030
Length of humerus on outer side	.110
Diameter humerus at epicondyles { transverse	.021
Diameter humerus at epicondyles { anteroposterior externally	.015
Length of ulna	.165
" radius	.141
Depth of olecranon distally	.015
Width of ulna at coronoid	.015
" " carpal facet (greatest)	.007
" radius at head	.016
" " carpal facets	.014
" " widest point distally	.016
Length of carpus at magnum	.015
" " unciform	.018

Measurements of Fore Limb.	M.
Length of lunar	.010
Depth "	.011
Length of magnum	.005
Depth "	.017
Length unciform	.009
Width "	.009
Depth " (total)	.014
" " of inferior facets	.007
Length of third metacarpal	.068
Proximal diameter third metacarpal { anteroposterior	.008
Proximal diameter third metacarpal { transverse	.008
Length of fifth metacarpal	.012
" median series of phalanges	.027
" first median phalange	.010
Width of do. proximally	.008
Length of second phalange	.006
Widths of median ungual phalange { proximally	.0070
Widths of median ungual phalange { medially	.0055
Widths of median ungual phalange { greatest	.007

The body of this animal was about the size of that of a red fox. The legs were more slender or elevated, and the head of course was shorter and thick.

The unique specimen on which our knowledge of this species rests was cut from a block of calcareous sandstone of the bed of the Washakie basin of the Bridger Epoch, near South Bitter creek, Wyoming Territory. The bones are generally in the relation of the position in which the animal died. The neck is depressed and the left fore leg raised so as to be in contact with it, and the head is raised so as to clear the left wrist.

Triplopus amarorum Cope.

The characters of the fore-foot of this species being unknown, it is not possible to determine its generic position. It has, however, one of the well-marked characteristics of the genus *Triplopus*, in the osseous enclosure of the *meatus auditorius externus*, through the ossification of the external prolongation of the otic bulla, and tympanic cartilage. I cannot therefore refer it to *Hyrachyus*.

It is represented by a skull from which a large part of both maxillary bones and the mandible have been lost, and which is accompanied by parts of the ulna and radius, parts of the ilium, a femur, and tibia, and nearly all of the posterior foot of the right side. The posterior parts of both maxillary bones remain, and they support each, the last superior molar tooth from which the external wall has been broken away. The portions of molars remaining exhibit characters which lead me to suspect that the

species does not belong to *Hyrachyus*. The anterior cross-crest of the molar preserved, is lobate, resembling the same ridge in the species of *Anchitherium*. The posterior cross-crest is uninterrupted. If this species possesses affinity with *Anchitherium*, it will perhaps possess three digits of the manus, in which case it will be referred to the *Triplopidæ*, in harmony with the indication furnished by the ear structure.

The *Triplopus amarorum* is much larger than the *T. cubitalis*, equalling the *Hyracodon nebrascensis*. It differs from the *T. cubitalis* in the stronger temporal ridges, and more elevated sagittal crest; also, in the shorter posttympanic process. The internal lobes of the last superior molar are connected by a basal ledge, not found in the *T. cubitalis*.

The interorbital space is wide and flat, and is most expanded at the postorbital angles.

From this point the face contracts rapidly forwards. From the same angle it contracts abruptly posteriorly to the rather narrow brain-case. The anterior temporal ridges are nearly transverse near the postorbital processes, and then converge more gradually, uniting opposite the posterior inferior border of the zygomatic fossa. The elevated sagittal crest diverges into two lateral supraoccipital crests, which contract as they descend, and continue to the extremities of the posttympanic processes. Although the postorbital angles are prominent, they cannot be called processes. The paroccipital processes are large, and are directed vertically downwards. They are separated by the usual concavity from the occipital condyles. The posttympanics are very short, forming only an angle projecting downwards at the anterior base of the paroccipitals, from which they are only separated by a notch. The inferior side of the tympanic bone is flat near the meatus, but opposite the stylomastoid fossa its posterior border is turned forwards, and is produced into a well marked process. It encloses a groove in front of it, which is continuous with the pterygoid fossa. The petrous bone is not inflated, and its inferior surface is divided into two longitudinal ridges. The inner is the less prominent, and is in close contact with the basioccipital. The postglenoid processes are robust and obtuse. The basioccipital is excavated in front of each of the condyles. The inferior surface is nearly flat, with a slight median keel. The pterygoid fossa is well defined, and is long and narrow. The posterior nareal trough is elongate, the descending pterygoid processes of the sphenoid originating as far back as the apex of the *os petrosum*. This species is especially characterized by the presence of an acute keel-like ridge, which extends horizontally above the foramina sphenoörbitale and opticum, and turns upwards anterior to the latter, terminating a half inch below the inferior base of the postorbital process. All the foramina are below it, but there is a fossa above it, opposite the interspace between the *f. opticum* and *f. sphenoörbitale*.

A supraorbital foramen pierces the frontal bone, a quarter of an inch within the superciliary border. There are five or six postparietal foramina, two of which are nearly on the squamosal suture. There is a postsqua-

mosal foramen, and also a not very small supraglenoid foramen. There is a small foramen anterior to the optic, and in line with the posterior part of the postfrontal angle. The *foramen opticum* is large, and is 10mm. in front of the *f. sphenoörbitale.* The latter is separated by a lamina from the large and vertically oval *f. rotundum.* The latter is joined by the large alisphenoid canal, whose posterior orifice is as large as the foramen ovale. The latter is large, and is well separated from the *f. lacerum anterius.* The *f. f. lacera* are well closed up, the *posterius* being reduced to what is probably the jugular foramen. The *f. condyloideum* is large, and is an anteroposteriorly placed oval. Its anterior extremity is opposite to and well separated from the *f. jugulare.*

The nasal bones are spread out posteriorly, and their posterior extremities are truncate. The coronal suture passes downwards at the narrowest part of the cranium behind the postfrontal angles. The squamosal bone does not reach the frontal. The parietal does not extend so far posteriorly as the lateral occipital crests, except near the squamosal.

The characters of the last superior molars have already been mentioned. The posterior transverse crest is uninterrupted, but the anterior consists of closely united internal and median lobes. The division is marked on the posterior side, and on the edge of the crest; the anterior face is plane. The longitudinal external crest sends a strong protuberance into the head of the valley, which is grooved on its surface. There is a strong anterior basal cingulum which rises to an anterior cusp. On numerous surfaces the enamel is slightly rugose. The inferior canine teeth are in continuous series with the incisors, and are slightly larger than they.

Measurements of Skull.	M.
Length from line connecting anterior borders of orbits to occipital crest	0.132
Length from line connecting posterior borders of orbits to occipital crest	.100
Width between postorbital angles	.100
" " anterior borders of orbits	.076
Elevation of occiput	.065
Width between mastoid ridges	.065
" " *ossa petrosa* at middle	.018
Diameters third superior true molar { anteroposterior	.0200
Diameters third superior true molar { transverse	.0205
Diam. second superior true molar (base) { anteroposterior	.0200
Diam. second superior true molar (base) { transverse	.0150

The portion of ilium remaining exhibits a rather narrow neck and a concave external face. A fragment of the femur shows a prominent third trochanter, with an obtusely rounded apex. The distal part of the fibula is not coössified with the tibia. Its shaft is exceedingly slender. The angles bounding the trochlear grooves and ridges of the tibia are of sub-equal

lengths. The median ridge is rather wide; the inner malleolus is narrow, has no distal facets and no distinct tendinous grooves externally.

The posterior foot is both relatively and absolutely smaller than that of *Hyrachyus eximius*. The trochlea of the astragalus is narrower and more deeply grooved. The crests are obtuse, and not so narrowed as in *Mesohippus bairdi*, nor are the malleolar facets of the astragalus so sharply defined as in the latter species. The external ligamentous fossa is, however, deep, and is bounded anteriorly by a low trihedral tuberosity not found in the *M. bairdi*. The head of the astragalus is not sessile as in *M. bairdi*, and has rather the proportions of *H. eximius*. The cuboid facet is a bevel of the external side of the distal extremity, as in *H. eximius*, and is not on a produced ledge, as in *M. bairdi*. The internal tuberosity of the head is not as much developed as in either of the species named. The navicular face of the astragalus is horizontally divided by a shallow ligamentous fossa. The calcaneum is much like that of *Hyrachyus eximius*. The cuboid face is less oblique than in that species, in the anteroposterior direction, and is less crescentic in outline than in *M. bairdi*. The sustentaculum is rather more extended transversely than in *H. eximius*, but resembles that species more than the *M. bairdi*, in wanting the deep groove at its base on the inferior side, which cuts it off from the rest of the calcaneum. The remainder of the inferior surface is flat, and not grooved for a tendon as in *H. eximius*.

The remainder of the tarsus includes the usual five bones, the three cuneiforms being present. They are in general a good deal like the corresponding bone of *Hyrachyus eximius*. The navicular differs in having a low transverse ridge on its proximal face, which fits the groove of the astragalus already mentioned. The hook of the cuboid is large. The external (anterior) face of the mesocuneiform has one-third the superficial area of the anterior face of the ectocuneiform. The entocuneiform is rather large, and is flat and subsemicircular. Its position is externo-posterior. The ectocuneiform presents facets to both the second and fourth metatarsals, that with the latter the largest. The distal halves of the metatarsals are lost. At their proximal portions they are of subequal width, as in *Hyrachyus eximius*, but the lateral ones are rather narrower at the middles of the shafts.

Measurements.	M.
Width of distal extremity of tibia	.029
" astragalar face "	.019
Length of inner malleolus	.007
" astragalus on inner side	.030
Depth of trochlea " "	.017
" head " "	.0145
Width of trochlea	.015
" navicular facet	.0195
Length of head from inner crest of trochlea	.005
" calcaneum	.058

Measurements.	M.
Length of free part of calcaneum	.037
Distal depth of the calcaneum	.016
Diameters cuboid face calcaneum { anteroposterior	.0145
Diameters cuboid face calcaneum { transverse	.0145
Length of navicular	.008
" cuboid	.0145
Transverse proximal width of three metatarsals	.027
Diameters of second metatarsal { anteroposterior	.014
Diameters of second metatarsal { transverse	.007
Antero-posterior diameter of third metatarsal	.0145
Diameters of fourth metatarsal { anteroposterior	.014
Diameters of fourth metatarsal { transverse	.012

This species was obtained in 1873 from the bad lands of South Bitter creek, Wyoming, from the Washakie basin of the Bridger formation. The locality is the same as that which furnished the *Triplopus cubitalis*, the *Achænodon insolens*, etc.

HYRACODONTIDÆ.

This family, which I characterized in 1879, includes, so far as yet known, the single genus *Hyracodon*, which is found in the Oligocene White river formation of North America. According to Marsh, the digits of this genus number three on both anterior and posterior limbs. It has a full series of incisor teeth in both jaws.

RHINOCERIDÆ.

This extensive family has left representatives in all parts of the Northern Hemisphere, and species still exist in the Old World. From the following table the range of variation of its genera can be readily seen :

I. Four anterior digits.

Incisors $\frac{2}{1}$; canine $\frac{0}{1}$; no horn; posttympanic bone distinct. *Aceratherium.*

II. Three anterior digits.

a. Posttympanic process not coössified with postglenoid.

Incisors $\frac{2}{1}$; canines $\frac{0}{1}$; no dermal horn ..... *Cœnopus.*

Incisors $\frac{1}{1}$; canines $\frac{0}{1}$; no dermal horn..... *Aphelops.*

Incisors $\frac{0}{1}$; canines $\frac{0}{1}$; no dermal horn..... *Peraceras.*

Incisors $\frac{1}{1}$; canines $\frac{0}{1}$; a tuberosity for a dermal horn on each nasal bone. *Diceratherium.*

Incisors $\frac{1}{1}$; canines $\frac{0}{1}$; a median dermal nasal horn..... *Ceratorhinus.*

Incisors $\frac{3}{2}$; canines $\frac{0}{1}$..... *Zalabis.*

Incisors $\frac{0}{0}$; canines $\frac{0}{0}$; dermal horn median; no osseous nasal septum.... *Atelodus.*

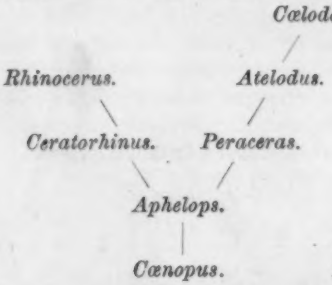
aa. Posttympanic process coösified with postglenoid;

Incisors $\frac{1}{1}$; canine $\frac{0}{1}$; dermal horn median; nasal septum not ossified.... *Rhinocerus.*

Incisors $\frac{0}{0}$; canine $\frac{0}{0}$; dermal horn median; nasal septum ossified..... *Cœlodonta*

It can readily be seen that the genera above defined form a graduated series, the steps of which are measured principally by successive modifications of four different parts of the skeleton. These are, first, the reduction of the number of the toes of the anterior foot; second, the reduction in the number and development of the canine and incisor teeth; third, the degree of closure of the meatus auditorius externus below; and, fourth, in the development of the dermal horns of the nose and its supports. While these characters have that tangible and measurable quantity which renders them available for generic diagnosis, there are others which possess a similar significance, and which I have noticed in an article published in the bulletin of the U. S. Geological Survey of the Territories for September 1879.

This series may be represented in genealogical relation, as follows:*



The early type, which corresponds most nearly with *Cœnopus*, and which preceded both it and the *Aceratheria* in time, is the genus *Triplopus* Cope, which has left a species in the Upper Bridger of Wyoming. Here the incisors are probably $\frac{3}{3}$ and the canines $\frac{1}{1}$. This formula is that of the Eocene tapirs, where the normal numbers $\frac{3}{3}\,\frac{1}{1}$ prevail. *Triplopus* further differs in the primitive condition of the premolars above, which, as in the *Lophiodontidæ*, differ from the molars in their greater simplicity. Thus it is probable that tapiroids, probably *Lophiodontidæ*, gave origin to the *Rhinocerıdæ*, as Marsh has suggested. And it is further altogether probable that the general type of deutition presented by the *Rhinoceridæ*, *Lophiodontidæ*, etc., which I have named the palæotheriodont, took its origin from the type which is intermediate between it and the bunodont, viz, the symborodont, as I have pointed out in an essay on this subject.

The first appearance of dermal horns was apparently in a pair placed transversely on the nasal bones, in species of Eocene *Lophiodontidæ* of the genus *Colonoceras*. The same character has been observed by Marsh in species of the Lower Miocene, which probably belong to the true *Rhinoceridæ*, and which he has called *Diceratherium*. This genus appears to have terminated the line exhibiting this structure, and the family in North America remained without horn. As we have seen, the types possessing the median horn arose in Europe, in the *Ceratorhinus schleiermacheri* of the Middle Miocene, and still survives.

*See American Naturalist, 1880, p. 611.

It may be observed in conclusion that a successive increase of size in the species of this line has taken place in North America with the advance of geologic time. Thus, their probable ancestors of the genus *Triplopus* were the least of all. The *Cœnopoda* of the White River formation were larger; the oldest *C. mite*, being the smallest. The *Aphelopes* of the Loup River or Upper Miocene formation were all larger, and were nearly equal to the large existing species.

TAPIRIDÆ.

The genera of this family are not numerous as yet. The oldest, *Listriodon*, appears in the Middle Miocene (Gers, France), and *Tapirus* is first found in the Upper Miocene (Epplesheim). The recent species of the family belong to *Tapirus* L., and *Elasmognathus* (Gill). A small species, the *Tapirulus hyracinus* Gerv., is from a bed at Perreal, France, which Pictet has identified with the gypsum of Paris (Oligocene). It is sometimes referred to this family, but is not sufficiently well known to determine its position. In America, *Listriodon*, or a genus which has not yet been distinguished from it, is found in the Miocenes.

The three genera are distinguished as follows:

Three anterior premolars different from fourth premolar and true molars; last inferior molar with heel..... *Listriodon.*

One superior premolar different from true molars; no heel of third inferior molar; nasal septum cartilaginous.... *Tapirus.*

Like *Tapirus*, but nasal septum osseous..... *Elasmognathus.*

CHALICOTHERIIDÆ.

Gill; Cope, American Naturalist, 1881, p. 340.

This family had numerous representatives during Eocene time, and a few species of *Chalicotherium* extended into Miocene time. The boundaries which separate the family from the *Lophiodontidæ* on the one hand and the *Menodontidæ* on the other, are not always easy to determine. From the former the symmetrically developed external Vs of the superior molars, and the double Vs of the inferior molars distinguish it. Yet in *Rhagatherium* the external Vs are not so well distinguished as in other *Chalicotheriidæ;* and in *Propalæotherium*, the anterior cingular cusp produces a part of the assymmetry found in the *Lophiodontidæ*. The character of the double inner cusps of the superior premolars, which distinguish the *Menodontidæ*, is only applicable to the last premolar in *Diplacodon* of the latter, while a trace of the additional cusp of this tooth is found in the Chalicotheroid *Nestoritherium*.

In using the following table it must be borne in mind that the number of the toes has been determined in a very few of the genera. Should any of them prove to have but three digits on the anterior foot, such genera must be referred to a new family intermediate between this one and the *Palæotheriidæ*.

PROC. AMER. PHILOS. SOC. XIX. 108. 2x. PRINTED MAY 16, 1881.

I. Internal cones of superior molars separate from external lobes.

A. Cusps of inferior molars not completely united;

a. External lobes of superior molars more or less conic.

Inferior premolars III and IV compressed, three lobed; a diastema both behind and before P-m. II.....*Rhagatherium*.

AA. Cusps of inferior molars united into two Vs.

a. Incisors present.

β. No diastema in front of second inferior premolar.

Second premolar without inner lobe; last molar with one inner cone.....*Leurocephalus*.

Second premolar with inner cone; last superior molar with an inner cone.....*Palæosyops*.

Second premolar with inner cone; last superior molar with two inner cones.....*Limnohyus*.

ββ. A diastema in front of second inferior premolar.

Two inner cones of last superior molar.....*Lambdotherium*.

aa. Incisors absent from both jaws.

Last superior molar with one internal cone.....*Nestoritherium*.

II. One or both internal cusps of superior molars united with the external lobes by cross-crests.

a. External cusps of superior molars more or less conic;

An anteroexternal cingular cusp.....*Propalæotherium*.

aa. External lobes of superior molars, inflected Vs.

β. No crescentic inner lobes.

No intermediate lobes.....*Chalicotherium*.

ββ. One or more lobes of each molar crescentic.

Intermediate lobes, and one internal cone of superior molars.....*Meniscotherium*.

The following regions have thus far furnished species of the above-mentioned genera:

Europe—*Rhagatherium, Propalæotherium, Chalicotherium*.

N. America—*Leurocephalus, Palæosyops, Limnohyus, Lambdotherium, Meniscotherium*.

Asia—*Nestoritherium*.

Of the American genera, *Leurocephalus* S. S. & O. has been found by the Princeton exploring expedition of 1877 in the Bridger formation, but I have not met with it myself. *Meniscotherium* Cope, is known from a single species found by myself in the Wasatch formation of New Mexico, and described in my report to Capt. G. M. Wheeler (1877).

FIG. 2. Part of right maxillary bone of *Meniscotherium chamense* Cope, from the Wasatch bed of New Mexico. From Report Capt. G. M. Wheeler, IV, ii, Pl. LXVI.

MENODONTIDÆ.

The known genera of this family are not numerous. They are defined as follows:

I. Vs of inferior molars probably incomplete; superior molars with intermediate tubercles.

Internal cusps of superior molars well separated.....*Acoëssus.*

II. Inferior molars with the crowns thrown into two Vs; superior molars without intermediate tubercles.

a. Last superior premolar only with two inner tubercles.

Incisors present.....*Diplacodon.*

aa. All the superior premolars with two interior cusps.

Six inferior incisors, canines very large.....*Dœodon.*

Six inferior incisors; canines very small .....*Menodus.*

No inferior, and four small superior incisors; canine very small.....*Symborodon.*

The first appearance of this family was in the Early Eocene in the genus *Acoëssus* Cope, which was a cotemporary of *Hyracotherium*, and which it resembles in some respects. Its typical species was called *Hyracotherium siderolithicum* by Pictet, its describer, but Kowalewsky has already expressed the opinion that the species does not belong to that genus. It is from the Lower Eocene of Mauremont, Switzerland. The remaining genera are, as yet, American, excepting one, which is represented by an Austrian species, not yet well known. *Diplacodon*, in its simpler premolars, approaches the *Chalicotheriidæ*, and is the oldest of the American genera. It is from the Uinta or Upper Eocene. *Menodus* and *Symborodon*, which include some species of gigantic size, belong in the White river or Oligocene, while *Dœodon* has so far only been obtained from the Truckee or Upper Oligocene.

MACRAUCHENIIDÆ.

But one genus of this family is known at the present time. The following are the dental characters of *Macrauchenia*. Formula: I. $\frac{3}{3}$; C. $\frac{1}{1}$; P.m. $\frac{4}{4}$; M. $\frac{3}{3}$, forming an uninterrupted series. The superior molars present two external Vs, and two oblique transverse crests, somewhat as in *Palæotherium*. The spinous foramina pierce the neural arch of the dorsal vertebræ (Gervais). There is no intertrochlear crest of the humerus, but the carpal facets of the radius are well distinguished. The internal malleolus is small, but the fibular malleolus is coössified with the tibia at an early age, and articulates with the calcaneum. The trochlea of the astralagus is well developed. The lateral digits are large, and the distal keels of the metapodials are continued on the anterior face of the condyle.

The position indicated by the above characters is a remarkable one. The uninterrupted dental series and the absence of intertrochlear humeral crest, are primitive features among ungulate *Mammalia*. The radiocarpal articulation is facetted as in higher ungulates, but lacks the inferior condyloid face of those types. The completeness of the metapodial distal keels is a feature of high specialization, only seen in the *Equidæ* of this order. The coössification of the external malleolus is also a character peculiar to the *Equidæ* among the *Perissodactyla*. There are two other characters which are not elsewhere found in this order, viz: the articulation of the fibula with the calcaneum, and the absence of the vertebrarterial canal. The former belongs to the *Artiodactyla* generally, and to the Proboscidæ, and the latter to the ruminant family of the *Camelidæ*. Thus the *Macrauchenïidæ* stand out as one of the most distinct of the families of the *Perissodactyla*, and one to which we may anticipate considerable accessions in future.

But two species of *Macrauchenia* are known, a larger, *M. patachonica*, and a smaller, *M. baliviensis*, both from the Pliocene formation of South America.

PALÆOTHERIIDÆ.

This family has been already defined on page 378. In its complex premolar teeth, which in the upper jaw resemble the molars in composition, it shows an advance over the *Chalicotheroid* and other genera of the Lower Eocene. In fact, it has not been found in the Lower Eocene, but commences in the Upper Eocene in the genera *Palæotherium* and *Paloplotherium*. Thence it extends to the very summit of the Miocene, and may even occur in the European Pliocene (*Protohippus*). Its members exhibit considerable range of variation in the details of the teeth and feet, but no striking break of family importance occurs. The most noteworthy interruption is that which is found between the *Palæotherinæ* and *Hippotheriinæ*, where there is a change in the form of the proximal extremity of the humerus from a tapiroid to a horse-like form, and a modification of similar significance in the molar teeth, by the addition of a deposit of cementum.

The characters of the genera are as follows:

I. *Palæotheriinæ*. Bicipital groove of humerus simple; teeth without cementum.

a. One or more internal tubercles of superior molars distinct.

External Vs of superior molars not well distinguished externally..... *Anchilophus.*

External Vs separated by a vertical rib; intermediate tubercles not connecting fore and aft..... *Paloplotherium.*

External Vs separated; intermediate tubercles extended fore and aft..... *Anchippus.*

aa. Internal tubercles of superior true molars continuous with the transverse ridges.

Inferior molars with two Vs only; lateral toes large..... *Palæotherium.*

Inferior molars with distinct internal tubercles; lateral toes small; a short fifth metacarpal..... *Mesohippus.*

Inferior molars with cusps at the inner extremities of the Vs; lateral toes small; no fifth metacarpal..... *Anchitherium,*

II. *Hippotheriinæ*. Bicipital grooove of humerus double; molars with cement in the valleys. (Intermediate tubercles connected fore and aft.)

a. One or more internal tubercles of superior molars distinct.

Inner lobes of inferior molars enlarged..... *Hippotherium.*

aa. Internal tubercles of molars not distinct.

Inner lobes of inferior molars enlarged..... *Protohippus.*

The genera of this family are generally of less antiquity than those of the *Chalicotheriidæ*, and they range from the Middle Eocene to the Pliocene. *Paloplotherium* is found in the Middle Eocene, and is, as might have been anticipated, more nearly allied to the *Chalicotheriidæ* than any other genus of this family. *Propalæotherium* is not far removed from it. *Anchilophus* is upper Eocene, and is allied to the genus just named, and also to *Pachynolophus* among the *Lophiodontidæ*. These early genera constitute by their similarity, the bond of connection between the three families which in their later and specialized forms are very different from each other. *Palæotherium* is chiefly found in the Upper Eocene, and *Mesohippus* is only known from the White river or Oligocene, an age between Eocene and Miocene. *Anchitherium* commences in the Middle Miocene and has *Anchippus* for a cotemporary. *Hippotherium* existed only in the latter part of the Miocene Epoch, consistently with the greatly specialized structure of its limbs and teeth, and the nearly allied *Protohippus* lived with it; while in Europe a species with the same type of molar teeth is found in the Pliocene epoch (Forsyth-Major). These forms were cotemporary with the *Equidæ*, which outlived them. They have many points of resemblance to that family, but nevertheless remain at a considerable interval from them in the structure of the feet.

The geographical distribution of these genera, so far as present knowledge shows, is as follows:

North America alone—*Mesohippus, Anchippus.*
North America and Europe—*Anchitherium, Hippotherium, Protohippus.*
Europe only—*Anchilophus, Paloplotherium, Palæotherium.*

EQUIDÆ.

The two genera of this family are distinguished as follows:

Internal lobes of superior molars subequal.....*Hippidium.*
Anterior internal lobes of superior molars much larger than the posterior.....*Equus.*

The genus *Hippidium* is extinct, and its species have been thus far found only in North and South America, in beds of Pliocene age. *Equus* made its appearance during the same period, and is represented by several existing species.

Besides the reduction in the number of digits, which is carried farther here than in any other family of *Mammalia*, there are several other characteristics of specialization. Thus in the dentition, the spaces between the tubercles are filled with cementum. These valleys are generally deep, owing to the prismatic forms of the molars. The cups of the incisors are completely developed, and also filled with cementum. There are two bicipital grooves of the humerus. The preceding characters are also found in the *Hippotheriinæ* of the *Palæotheriidæ.*

The *Equidæ* adds another evidence of greater specialization than the latter group in the structure of its feet, *i. e.*, the distal metapodial keels are completed forwards, as in most ruminants.

The similarity of the modifications which have supervened on the Artiodactyle and Perissodactyle lines in attaining their most specialized extreme has often been noticed. I repeat them here in tabular form in three columns. These show (Table I) the modifications in which the *Equidæ* and *Bovidæ* are identical or nearly so, which place them at the heads of their respective orders; Table II, those in which the *Equidæ* are the more specialized of the two; and Table III, those in which the *Bovidæ* displays the highest differentiation.

	Table I.	Table II.	Table III.
1	Obliteration of first premolars.	Cupping of incisor teeth.	Absence of superior incisors.
2	Selenodont and prismatic character of molars.	Deposit of cementum in teeth.	Trough-shape of odontoid.
3	Flattened odontoid process.	Double bicipital groove of humerus.	Greater involution of lumbar prezygapophysis.
4	Reduction and coössification of ulna.	Reduction of metapodials to one.	Fibular articulation of calcaneum.
5	Intertrochlear crest of humerus.		Distal ginglymus of astragalus.
6	Distal facets of radius.		
7	Involution of lumbar prezygapophyses.		
8	Elongate sacrum.		
9	Shaft of fibula atrophied, and its distal extremity coössified to tibia.		
10	Reduction in number of digits.		
11	Anterior extension of carinæ of metapodial bones.		

Note on the Structure of the Posterior Foot of Toxodon. By E. D. Cope.

The position of the genus *Toxodon* in the system of Mammalia, is a question upon which few authorities have expressed positive opinions, and which is generally regarded as still an open question. In the lack of certainty on the subject, a separate order, the "*Toxodontia*," has been proposed for its reception. It is known that the genus is ungulate, but the opinions of authors are much divided as to its relations to the three principal orders included under that head. Resemblances to the *Proboscidea* have been detected, but Professor Gervais (Comptes Rendus, 1878), asserts that there is a close resemblance to the genus *Hippopotamus* in the structure of the posterior foot.

Having come into possession of remains of *Toxodon*, which include the greater part of the skeleton, I make a few observations on the affinities suggested by the posterior foot, the only portion just now accessible in my collection. The calcaneum and astragalus have been more or less imperfectly figured by De Blainville and Burmeister, but no one has, to my knowledge, represented the entire foot. The calcaneum is rather short and stout, and its external convex tuberosity is of unusual size. Its articular surface is divided into two subequal parts, the internal of which supports the astragalus, the external the fibula. Thus the fibular articulation is of unusual size. The cuboid facet is on the inferior face of the extremity of the calcaneum, thus looking directly downwards when the bone is prone. In order to articulate with the remainder of the foot, the calcaneum must have been inclined upwards and forwards at an angle of 45°, and the cuboid inclined downwards and forwards at a similar angle. That the axis of the astragalus had the latter inclination is proven by the fact that the superior plane of the sustentaculum lies at that angle to the axis of the remainder of the calcaneum. The great convexity of the external tuberosity for the astragalus will also permit of such a position for the astralagus. The navicular facet of the astragalus is plane and truncates the bone somewhat inferiorly as well as distally, so as to present in the same way as the cuboid. There is probably no cuboid facet. I have not seen the cuneiform bones. The metatarsals and phalanges are robust and rather short. The distal keels of the former are posterior and rudimental. Their proximal extremities have a small lateral tarsal facet as well as the principal one. The median digits are of unequal length, and the lateral ones are much shorter, but robust. Whether there are four or five digits I cannot definitely ascertain.

The above characteristics are very significant. They at once refute any supposition of affinity to the *Artiodactyla*, whether suilline or ruminant. The form of the astragalus and wide fibular condyle of the calcaneum, opposes the reference of the genus to the *Perissodactyla*. On the other hand, all the characters of the feet thus far adduced, are found in the *Proboscidea*. They are not only those of that order, but they are carried to a degree of exaggeration, as though *Toxodon* represented a high grade of

specialization of that order. The posterior feet were more truly plantigrade, for the extremity of the calcaneum reached the ground, while the instep was elevated above it, being supported, no doubt, by a more or less elastic pad. This arched or angulate plantigrade type of foot, has a remote parallel in that of man. It is quite unique among ungulate *Mammalia*.

What difficulties the other parts of the skeleton may present, I do not yet know, but I perceive nothing in the dentition which forbids the reference of *Toxodon* to the *Proboscidia*. The dentition is scarcely more different from that of *Mastodon* or *Dinotherium*, than that of *Bos* is from *Dicotyles* or *Hippopotamus*. The former genera may be the extremities of a series whose intermediate members are as yet undiscovered. In the latter case, the intermediate forms are mostly known.

Stated Meeting, May 6, 1881.

Present, 22 members.

President, Mr. FRALEY, in the Chair.

Capt. McCauley and Mr. Ellis Yarnall, two newly-elected members were introduced to the presiding officer and took their seats.

Visitor, Lieut.-Commander Gorringe, U. S. N.

Letters acknowledging receipt of diplomas were received from Messrs. W. B. Taylor, C. P. Patterson, Asaph Hall, J. J. Stevenson, C. F. Adams, J. F. Mansfield, A. S. McCreath, J. Douglas, Jr., L. M. Haupt, R. H. Alison, O. W. Holmes, Alvan Clark and J. J. Sylvester.

Letters accepting membership were received from Mr. Alvan Clark, dated Cambridgeport, Mass., April 25th; Prof. J. J. Sylvester, dated Baltimore, April 25th; Judge Wm. Butler, dated Philadelphia, May 6th; Prof. E. A. Barber, 4101 Walnut street, Philadelphia, April 25th, and Mr. W. W. Griscom, 2009 Pine street, Philadelphia, April 18, 1881.

Letters of acknowledgment for publication, and letters of envoy were read from the Musée Guimet, Herr Sommerbrodt, of Breslau, April 11th, 1881; the Physico-Central Observatory, St. Petersburg, the Smithsonian Institution, April

15th, and the Bureau of Ethnology, J. W. Powell, Director, April 25th.

Donations for the Library were received from St. Petersburg Botanical Garden; Swedish Bureau of Statistics; Dr. Julius Sommerbrodt, of Breslau; R. Belgian Academy; Geographical Society, of Bordeaux; Revista Euskara, of Pamplona; R. Academies at Turin and Rome; R. Astronomical Society; Society of Antiquaries; Dr. C. W. Siemens; Augustus Mongredien; London Nature; Hon. R. C. Winthrop; Boston Academy; American Journal of Science; American Philosophical Association; Essex Institute; American Antiquarian Society; Harvard University Bulletin; Samuel H. Scudder; Astor Library; Microscopical Journal; James J. Talbot; Geol. Survey of New Jersey; Penna. Magazine, Engineer's Club, Franklin Institute, Pharmaceutical Association, Prof. E. A. Barber, Numismatic Society, Penna. Hospital for the Insane, Penna. Museum and School of Industrial Art, Am. Journal of Pharmacy, Medical News, Prof. L. M. Haupt, Mr. Henry Phillips, Jr.; Maryland Historical Society; Smithsonian Institution, Anthropological Society; War Department; Hon. W. D. Kelly; Mr. Jed. Hotchkiss; Mr. Chas. C. Jones, of Savannah; Wisconsin Nat. History Society; Ministerio de Fomento.

The death of Prof. A. Delesse, at Paris, March 24th, aged 63, was reported.

Mr. Frazer exhibited coins; and also specimens of the granite, cement, lead, bronze and steel used by Egyptians in erecting the obelisk now in New York, and sections of the granite under the microscope.

On motion of Mr. E. K. Price, the thanks of the Society were voted to Lieut.-Commander Gorringe for the great gratification he had afforded the members, by the exhibition of many rare and valuable ancient coins of Egypt, Macedonia, Greece and Rome; and to Mr. D. S. Holman for his assistance in rendering them visible to all by his megascope.

Mr. Ashburner exhibited a suite of maps of one of the British coal fields.

Dr. Chance communicated a paper entitled "An analysis of the Fire-damp Explosions in the Anthracite coal mines, from 1870 to 1880."

Mr. Fraley reported that he had received the last installment of the Michaux legacy, amounting to $131.18, and, paid it over to the Treasurer.

And the meeting was adjourned.

An Analysis of the Fire-damp Explosions in the Anthracite Coal Mines, from 1870 *to* 1880. *By H. M. Chance, M. D.*

(*Read before the American Philosophical Society, May* 6, 1881.)

The table which forms the subject matter of this paper is compiled from the reports of the Inspectors of Mines, for the years from 1870 to 1879 inclusive. In it are included all recorded explosions, whether resulting in serious or trivial casualties. The majority of these were caused by the ignition of but a few cubic feet of explosive mixture, but some were terrible disasters, the victims of which may be numbered by scores.

The total number of recorded explosions is 639, the number of casualties 1127, and of these 225 resulted fatally. As the reports for two or three years are not complete, these figures do not represent the exact number of casualties; but they express sufficiently well the ratio between the explosions and the number of miners injured by them.

During these years the explosion of fire-damp was the cause of sixteen per cent. of the total casualties reported by the Inspectors, of eleven per cent. of the fatal accidents and of eighteen per cent. of the non-fatal casualties.

EXPLOSIONS OF FIRE-DAMP.

	1870.	*1871.	1872.	1873.	1874.	†1875.	‡1876.	1877.	1878.	1879.	Total.
January	0	8	3	2	2	3	5	7	2	4	36
February	2	4	4	2	5	3	6	4	1	5	36
March	0	2	6	3	3	3	4	5	0	8	34
April	4	7	14	6	5	2	7	8	2	10	65
May	3	10	8	9	8	1	11	9	2	18	79
June	1	6	7	13	12	5	4	6	4	3	61
July	3	11	5	4	7	7	2	7	4	6	56
August	3	10	13	10	5	3	2	3	6	9	64
September	4	9	6	10	9	12	4	2	0	10	66
October	8	7	10	6	8	6	8	7	2	10	72
November	6	3	2	7	9	5	4	7	2	7	52
December	6	6	3	2	4	9	8	6	4	10	58
Total	40	83	81	74	77	59	65	71	29	100	679

*Explosions in Eastern District of Luzerne, not included in the report for 1871.

†Explosions in Southern District of Carbon and Luzerne, not included in column for 1875.

‡Shamokin District statistics omitted from report for 1876.

The table is arranged to show the number of explosions occuring in each month of the year for ten years, and the right hand column the number for each month of the whole period.

An inspection of latter column shows at once that from April to October the number of explosions is far greater than that of the remaining months of the year. In these seven months 463 explosions are recorded, an average of sixty-six for each month, but for the remaining five months (Jan., Feb., March, Nov. and Dec.) we find but 216 explosions, an average of but forty-three for each of these months.

Temporary or partial suspension of mining during some part of these months in certain years may partly account for this difference, but is inadequate to explain so marked a contrast between the groups of warm and cold months.

It seems probable, that if a closer differentiation could be made, it would be found that many of the explosions occurring during the warm months, happened at or immediately following a short period of unusual warmth, during which the ventilating current was somewhat diminished in strength. At such a time, when unusual warmth with high barometer had existed for one or two days, a sudden fall in the barometric column, presaging a local or general storm would surely be followed by an increased outflow of gas which might readily become explosive at the working face while the air still remained safe in the upcast.*

The low rate of July may be due in part to partial suspension of operations during that month, and the high rates of November and December, high compared to those of January, February and March, are probably due in part to steady working to supply the winter demand, and the low rates of the remaining winter months to partial suspension of work.

The maximum rate in May, and the next in rank, October, are just five months apart. Are these months subject to greater and more sudden and frequent barometric changes than others in this part of the United States?

A list of the most serious colliery disasters in Great Britain, from 1778 to 1866 inclusive, develops the interesting fact that out of forty-five explosions, ten occurred in June and eight in December, periods just six months apart.

The table is as follows:

Months.	*No. of Explosions.*
January	2
February	1
March	4
April	0
May	4

*If one per cent. of gas in the upcast corresponds to a maximum of five per cent. at the working face (in places where "accumulations" are found) an increase of two per cent. in the upcast, making three per cent. in all, a perfectly safe percentage—means an increase to seven per cent. at the working face; a condition of great danger. The above described meteorological conditions may often bring about just such a result.

Months.	*No. of Explosions.*
June	10
July	4
August	3
September	2
October	4
November	3
December	8
Total	45

This list embraces only the explosions resulting in great loss of life. The minimum loss of life was 20, and the maximum, the Oaks Mine disaster, December, 1866, was 362; the loss of life aggregates 2621, an average of more than 58 for each disaster.

The occurrence of three of these explosions on June 2, 1862 (at Washington, Guindræth and Coppal), and two of the most fatal on December 12th and 13th, 1866 (the "Oaks" and "Talk o' the Hill"), by which 362 and 92 lives were lost, certainly point to atmospheric disturbance as the immediate cause. The occurrence of a large percentage of these disasters at semi-annual periods, June and December, seems to indicate the occurrence (in Great Britain) during these months of unusually high barometer, followed by a decided fall, as the probable cause of these great outbursts of gas.

But the problem I have been considering is somewhat different, for the table embraces *all* the explosions, whether large or small, occurring during the ten years. Is shows a decidedly larger number for the warm than for the cold months, and therefore points primarily rather to impairment of ventilation from high temperature than to barometric changes as the true cause of the difference; but the occurrence of two maximum periods, May and October, seems to indicate that barometric changes have also exercised an important influence on the relative efflux of gas.

The *amount* of rise and fall does not seem to have a perceptible effect, for the monthly barometric range is *greatest during the cold months*, whereas fire-damp explosions are most frequent during the warm months. Frequent and *abrupt* changes from high to relatively low barometric pressure, are the probable cause of many explosions, though the movement of the mercury may not amount to more than one-eighth or one-quarter of an inch. An unusually *high* barometric column is always an intimation of coming danger.

Stated Meeting, May 20, 1881.

Present, 5 members.

President, Mr. FRALEY, in the Chair.

Letters accepting membership were received from E. Malézieuz, dated Paris, March 4th; from Claudio Jannet, 38 Rue de Varennes, Paris, May 7th; and from Paul Leroy Beaulieu, Paris, 27 Avenue de Bois de Boulogne, May 4th.

A letter acknowledging diploma was received from J. Ericsson, dated New York, May 14th.

A letter of envoy was received from the Royal Geological Society of Cornwall, May 3d, 1881.

Donations for the Library were received from the Royal Prussian Academy; the Botanisches Centralblatt, Kassel; Zoologischer Anzeiger; the Geographical Societies in Paris and Bordeaux; Editors of the Revue Politique; Revista Euskara; the Journal of Forestry, London; Royal Geological Society of Cornwall; Essex Institute, Salem, Mass.; Museum of Comparative Zoology, Cambridge; Boston Society of Natural History; Young Men's Association, Buffalo; Mr. A. R. Grote, Buffalo; Zoological Society and Franklin Institute, Philadelphia; U. S. National Museum, Washington; American Antiquarian, Chicago; Kansas Historical Society, Topeka; Revista Cientifica Mexicana, and the Ministerio de Fomento, Mexico.

Mr. Price presented in the name of Mrs. Ellen Keene Mitchell a certificate of membership of John Lukens, dated the 20th day of January, 1786, and signed by the officers. John Lukens was Surveyor General of Pennsylvania from December 17th, 1761, until his death in October, 1789. Mrs. Mitchell is his lineal descendant.

On motion of Mr. Price,

Resolved, That this Society present their thanks to Mrs. Ellen Keene Mitchell for the certificate of membership in this Society of her ancestor, John Lukens, Surveyor General of Pennsylvania, dated the 20th January, 1786, signed by the officers of that date.

Mr. Lesley showed a translation of the Lord's Prayer into Egyptian hieroglyphics by Commander McCauley, U. S. N.

Pending nominations No. 934, 935, 936 were read.

The proceedings of the last meeting of the Officers and Council were submitted.

The meeting was then adjourned.

Notes on an Egyptian element in the Names of the Hebrew kings, and its bearing on the History of the Exodus. By J. P. Lesley.

(*Read before the American Philosophical Society, March* 4, 1881.)

It was accounted a great discovery when, a few years ago, papyri were found stating the number, cost and transportation of squads of APURU from the Delta to the mining districts in Nubia. These official documents were a sort of Indian bureau agent reports of the age of the XIX Dynasty, say 1400 B. C.; and therefore the word APURU was suspected of being the Egyptian equivalent of the Hebrew word עִבְרִים, OBRIM, Hebrews.*

Gesenius gives some good reasons for the common etymology of the word from the verb OBR, 'ăvăr, *to pass.*†

It occurs in Chaldee as Eber, "the country beyond" the Euphrates. And therefore the LXX translates "Hebrew" in Gen. 14 : 13, by ὁ περάτης, the *immigrant* or *emigrant.*

The Biblical usage of the word seems to be restricted to cases when foreigners were speaking of the Israelites, Gen. 39 : 14, 17, &c.; or when Israelites were speaking of themselves to foreigners, Gen. 14 : 15, &c.; or when some opposition to foreigners is in question, Gen. 42 : 32, &c. It seems, however, rather absurd to put the word with this meaning into the mouth of the Hebrews themselves. One can very well imagine them calling surrounding extra-limital tribes "outsiders," "people over there;" but to imagine them accepting such a title as their own, contravenes all that we know of their proud and exclusive estimate of themselves, unless these sentiments be considered a product of later times.

The difficulty is enhanced by the fact that, whereas in Gen. 50 : 10, 11; Deut. 1 : 1, 5; 3 : 8, 20, 25; 4 : 41, 46, 47; Josh. 1 : 14, 15; 2 : 10; 9 : 10;

*The pronunciation of the word by the Masorites, after the time of Christ. 'IVRIM, is of no importance, except as indicating the probable guttural aspiration of the ע, by which the Greeks were lead into writing the word Ἑβραῖοι, Hebraioi.

†This root is widely distributed, as in the english *over*, german *über*, latin *super*, greek *'ubris* (pride), *upper*, and to *pour*, *outpouring* (overflowing or passing bounds).

12 : 1 ; 13 : 8, 32 ; 14 : 3 ; 17 : 5 ; 20 : 8 ; 22 : 4 ; Judg. 5 : 17 and Isai. 8 : 23, the root עבר *beyond* is applied to the Gilead and Bashan (east) side of the Jordan, it is applied in Josh. 5 : 1 ; 9 : 1 ; 12 : 7 and 1 Chron. 26 : 30 in directly the opposite way, to the Ephraim and Judah (west) side of the Jordan.*

The only plausible explanation comes from the fact that the tribes settled to the east and to the west of the Jordan spoke of each other as *beyonders ;* and the song of Deborah shows in how bitter a spirit the epithet could be employed ; while the address of Jepthah (the Gileadite) seems to ignore the tribes on the west side altogether, as if they were not Israelites.

If the theory be tenable that the Abrahamidæ or Terahites migrated towards Palestine not from the direction of Kurdistan and Assyria, but from Babylonia, by way of Yemen, up the east coast of the Red Sea, through Midian, into Edom and Moab, long before the Exodus, it follows that they would be recognized by the Horites or troglydites (*Hor*, a cave) of Petræa, as "foreigners" (Hebrews), and might possibly be compelled by circumstances to accept the epithet.

If part of this migration was represented by the Kenites, and if Moses himself was the son† of the Kenite Scheik Jethro‡ and was sent by him to bring another enslaved part of the migration, back, over the desert, to their comfortable settlements in Petræa,—then it becomes probable that the name "Hebrews" is merely a patronymic for *Beni Héber*, the descendants of Heber the (original) Kenite.

Gesenius long ago wrote : "Heber, the founder of the Hebrew race, Gen. 10 : 24, 25 ; 11 : 14, 15," and referred to the expression *Beni Heber* in Gen. 10 : 21, and the poetical expression *Heber* (Hebrews) in Num. 24 : 24.

The LXX spells Heber, *Ἐβερ*, and *Ἑβερ*. He was son of Salah and father of Peleg (the Philistines). The Jews have always considered him their national patronym. The Heber of Judges 4 : 11, 17 ; 5 : 24, is spelled differently, חבר, LXX *χαβερ*, *Chaber*, and he must have lived a century or two *after* Moses ; for he was a descendant of Hobab, son of Jethro and brother-in-law of Moses. Many changes had occurred. The Kenites were amalgamated with the other Hebrew tribes; and this wealthy sheik, Heber, who had married Jael, lived in the extreme north of Palestine, and was a friend of the King of Damascus. The rough spelling of his name suggests a northern patois.

In the word *Ephraim*, then, we may have merely another dialectic spelling of the word *Ebraim* (Hebrews.) It is written in our Hebrew texts אפרים, APRIM, and is a sufficiently precise reproduction of the APURU of the papyri. As the latins nasalized their final M, and ignored it in scanning, so the Hebrew plural final *im* would disappear in Egyptian, and be replaced by the regular Egyptian plural termination U.

* *Beyond* the Arnon, *beyond* the sea, and *beyond* the river (Euphrates ?) are also expressions in use.

† Son-in-law.

‡ The same as, or the son of Raguel, "friend of God."

If Egyptologists be now inclined to reject the APURU=OBRIM (Hebrew) theory, they can hardly have reason to reject an APURU=APRIM (Ephraim) theory, if it were suggested; and the object of these notes is to suggest it, with the grounds for its consideration; not, however, on the side of Egyptian philology, but on the side of Hebrew history.

A recent anonymous work on "The Hebrew Migration from Egypt" (London, 1879), draws attention to the fact that the account of the Exodus collates two distinct stories from different sources, in one of which the term *Israelites* only, and in the other the term *Hebrews* only, is applied to the emigrating people; and that one of these stories speaks also of a "mixed multitude" forming a separate part of the emigration.*

Jacob represents the Hebrew race in the traditions of Judah and the south; Joseph represents the Hebrew race in Egypt; Ephraim in the history of the northern division; and Reuben in that of the transjordanic provinces. The distinction between the *Beni-judah* and *Beni-israel* pervades Palestinian literature from first to last. It is plain to see that some stirpal barrier divided the northern from the southern parts of the country, and that they were never united except during the short dynasty of David and Solomon. Judah was not Israel, and never had been. Ephraim alone was Israel. "To your tents Oh, Israel; what part have we in David . . . so *Israel* departed unto their tents. But over the *Beni-Israel*, who lived in the cities of *Judah*, Rehoboam continued to reign." His own people were not Beni-israel, but "*men of Judah*."

If the children of Israel then were Hebrews and not Jews, and if Ephraim was practically Israel,† the exclusive and specific use of the term *Hebrews* in the story of the Exodus practically confines the history of the exodus to the *Beni-joseph*, the descendants of Ephraim and Manassah.

But the name *Manassah* is not a Hebrew but an Egyptian word; while the name *Ephraim* is par excellence a Hebrew word. There is a strong probability then that while Ephraim meant the Hebrew division of the emigration, Manassah meant the "mixed multitude," partly Egyptian and partly perhaps Kenite, Midianite, or what not.

The word *Manassah* reappears in Hebrew history, after the lapse of 500 years, as the name of a king of Judah (not of Israel); and evidently not as a survival of what had been a common personal or family name, but as an Egyptian name; for, it comes to view in company with other Egyptian names, and in consequence of the alliance of Solomon with a reigning Pharaoh, whose daughter he made his queen, or first lady of the harem. His other wives were princesses of surrounding Shemitic tribes. Their children were baptized with Shemitic names; but *her* children probably received Egyptian names.

*A short resumé of the whole book is given in the 15th or last chapter. Whatever the author might think of the suggested connection of *Hebraim* and *Ephraim*, cannot be said. It certainly fits into his exegesis.

†The rest of the tribes (except Levi) play a curiously subordinate rôle in the whole story; are dropped out of it early, and are scarcely even incidentally mentioned afterwards.

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After the crown of Solomon had descended to the Shemite Rehoboam (whose mother was Naamah the Ammonite), the Pharaoh Sheshonk (Shishak) looted Jerusalem, in the cause of his (Shishak's) protégé, Jeroboam of Israel.

Jeroboam's wife *Maachah* carried an Egyptian name; she was the daughter of Abishalom (father of peace), a Shemite, who had probably married an Egyptian girl, perhaps one of those bred at Solomon's court.

Abijah, Jeroboam's son and successor, had a pure Shemite name, if the priestly Judean chronicler (2 Chron. xiii, 1) spells it rightly; for it means "My father Jah." It has a variant, *Abijahu*, meaning "whose father is Jah."

The Judean historian of 1 Kings (xv. : 1, &c.), always spells it *Abijam*, which should mean in Hebrew "My father the sea;" but Gesenius translates it "Father of the sea; *vir maritimus;*" the sailor.

Without the points these two forms read simply ABIE (LXX *'αβιά*), and ABIM (LXX *άβιου*). The first form is anticipated in Abiah ABIE, (LXX. again *ἀβιά*) one of the sons of Samuel (*pater Jehovæ, vir divinus, e. g. ish elohim*, Ges. !)—and again in *Abihu*, ABIEUA, (LXX *άβιούδ*) second son of Aaron. The absurd and only (Hebrew) etymology suggested for this name is "Father of him," "to whom He (God) is father." Nothing can be more forced and improbable.

It is very significant that, of the four sons assigned to Aaron, viz., Nadab, Abihu, Eleazer and Ithamar, two of them, Nadab and this *Abihu*, were struck dead "for offering strange fire," that is, for worshiping Jehovah according to some foreign rites, doubtless Egyptian.† The הוא (HUA) final in Abihu's name is so strongly pronounced that it must have some signal significance, and it suggests the *αχυ* sphynx god of the horizon. If Abijah be My father Jah, *Abihua* is *Father Αχυ*.

Moses' name is acknowledged to be pure Egyptian. *Aaron's* name is as positively Egyptian as evidence can make it; for ARN is the most sacred name for the ark, box, ship of Isis, sarcophagus, &c. And there is no good reason to be urged against an Egyptian etymology of the name of Aaron's tenth descendent, the high priest *Abiathar*, ABIThR (LXX *'αβιάθαρ*) from the goddess *Athor*, or Hathor, "the habitation of Horus," meaning *the temple*, or shrine. *Abiathar* would then mean simply the "father," or "guardian of the shrine."

*This is a mere confession of etymological desperation; and casts discredit on the whole series of names beginning with Ab and Abi. One might just as well propose to derive the Hebrew word אביונה *Abijonah*, "desire, appetite, lust," also "the berry of the caper bush" (thought to be provocative of lust) from Abi and Jonah—"Father of Jonah," or "whose father is Jonah." So, some have asserted that *Abihud* (1 Ch. 8 : 3) must have meant "whose father is Judah;" *Abigail* "whose father is joy," *Abidan* (Num. 1 : 11), "father of the judge," although he was himself a judge; &c. Only when a name is clearly written out (like *Abiezer* אביעזר, "father of help," *i. e.*, the beneficent), can these etymologies be considered probable.

† Compare the Apis rebellion conducted by Aaron, for which he also perished.

To return now to the Kings of Judah; *Abijah* or *Abijam* walked in all the sins of his father, that is, did *not* worship Jehovah; or, at least, worshiped other deities also.

Asa, son and successor of Abijam, had one of the purest of Egyptian names; a name borne by the Fourth Pharaoh of the Fifth Dynasty, called "the good *Assa*," and by the Eighth of the same dynasty, called simply "*Assa*," with the forename *Tatkara*. The word meant, in Egyptian, image or statue. Queen Hatasou called the temple she built to Hathor, *Assassif*.

It is an odd but characteristic clerical error in 1 Kings xv, 10, that the scribe repeats of Asa what he had before said of his father, Abijah, that his mother (not grandmother) was *Maachah*, daughter of Abishalom. The chronicler (2 Ch. xi, 20) says that Maachah was Abijah's mother, and says nothing about Asa's mother. But he lets us into the state of Jehovah worship thus: Azariah went to meet Asa returning from a great victory over the Cushites, and said...."Jehovah is with you...*Now for a long season Israel (hath been) without the true God*, and without a teaching priest and without law....When Asa heard these words....he put away the abominable idols out of all the land of Judah and Benjamin....and renewed the altar of Jehovah," &c. The baby *Asa* might well bear a pure Egyptian name.

Jehoshaphat was the son and successor of Asa. Both he and his mother, Azubah daughter of Shilhi, have therefore Hebrew names; and he seems to have followed his father's faith in Jehovah, and to have been in fact a zealot, establishing a sort of colportage system throughout the south country, and appointing clerical judges (Shophetim) everywhere.

Jehoram, Jehoshaphat's son and successor, had six brothers; and all seven had honest Hebrew names. But Jehoram slew his six brothers; married Ahab's daughter; and let loose idolatry again in Judah. After a long and disastrous reign he is made to die, like the apostate Julian, of some horrible bowel complaint, as a punishment for his defection from Jehovah, and was refused burial in the royal tombs (an Egyptian punishment).

Ahaziah, son of Jehoram, reigned but one year, and was murdered by Jehu, the usurper of Israel. All his family were then destroyed by his mother, Athaliah, except little Joash, who was concealed by the high priest, Jehoiada, in the temple for seven years; and then a revolution placed him on the throne, which he rededicated to Jehovah.

Joash, is certainly Hebrew for *Theodore*, "God given." The name was borne not only by this eighth King of Judah, but also by the twelfth King of Israel, which secures its semitic character. His mother's name was Zibiah of Beershebah. After Jehoiada's death, this king plunged into the indulgence of all the popular idolatries; and among the violences which occurred were:—the famous stoning of the prophet Zechariah; the slaying of Jehoiada's sons; the victorious invasion of the Syrians; and the assassination of Joash.

Amaziah (a Hebrew name) succeeded to the throne. His mother was Jehoaddan of Jerusalem. He served Jehovah; defied Joash of Israel; was defeated and ruined, and afterwards assassinated. His piety towards Jehovah stood him as little in stead as did his descendant's, Josiah.

Azariah (*Uzziah*), his son, had a long, pious and prosperous reign of fifty-two years. Jecholiah of Jerusalem was his mother. He became a leper, and his son Jotham acted as regent.

Jotham's mother was Jerusha, daughter of Zadok (a priestly name), and he worshiped Jehovah, like his father. One would not expect anything non-semitic in his name, יותם (IOThM), and it is probably rightly translated "Jehovah (is) upright;" but it is constructed precisely on the Egyptian plan in all those cartouches containing *nefer* and *tat*. It is an ancient name also, for it occurs in the history of the times of the Judges (9: 5) as the name of a son of Gideon (LXX γεδεων, גדעון, perhaps "tree-cutter," or impetuous warrior. Ges.).

Ahaz, his son, succeeded, and sent for Tiglath Pilezar to come and carry off the *Beni-Israel*. He sacrificed his own son to Moloch; and one is sorry not to find his mother's name recorded, for she was probably a foreigner, and gave him his name.

The curious thing about this word אחז, LXX 'αγαζ (Josephus 'αχαζης) in this case is, that it stands alone, pure and simple; whereas in the cases of *Ahaz*iah the sixth King of Judah, his direct ancestor, and *Ahaz*iah the seventh King of Israel, the word is joined to the name of Jah, "whom Jehovah sustains," exactly equivalent in sense to the Pharaonic *Ra-tat-ka*, 16th cartouche on the 2d tablet of Abydos, *Sol sustains life;* and *Ra-tat-f*, 32d cartouche on the same, *Sol his sustainer*.

Ahaz would represent the *tat* standing alone in the cartouche.

It is very remarkable to find *Asa* and *Ahaziah* connected in Judah, and *Assa* the Pharaoh of Egypt with the surname of *Tatkara*.

Ahaz reigned sixteen years, and seems to have been an exceedingly heathenish prince, respecting neither Jehovah, the priesthood, nor the prophetic schools. He closed the temple of Solomon. No wonder he dropped the Jah from the name which he inherited from his ancestor *Ahazjah* five generations back. Under his auspices the Phynicean Baal and Astarte-worship flourished, as it did at that time in the Delta of Egypt.

His politics, however, were not Egyptian. He called in to his aid, not the power of Egypt, but the army of Pul, King of Assyria, and became his vassal. In consequence, Pul's successor, Tilgath Pilezar, added Gilead and Galilee to his empire, wiping out the true *Children of Israel* from the Promised Land. The hoarded wealth of Judah was the price paid for a merely nominal security against the same fate. From this date of Ahaz's reign in Judah we hear no more of Ephraim; the lands of which were now crowded with forced colonists from Mesopotamia, bringing their languages and religions with them, and mixing these up with the Hebrew language and the worship of Jehovah.

Hezekiah followed Ahaz on the throne of Judah, and reigned twenty

nine years. His mother, Abi (*my father*), was evidently a Jewess, the daughter of a Jew, Zakariah. She gave her son a genuine Hebrew name, HZQ-IE, חזקיה, "the strength of Jehovah;" for she was a zealous worshiper of the true faith, and reared her son in its rigid observance. The verb חזק (hazk) means to bind, hold fast, adhere, cleave to, make firm, strengthen and be strong. In this secondary sense it agrees with the Egyptian *Tat*, and illustrates the construction of such royal names. But it can have no direct connection with Egypt; for it is amply explained by ths Hebrew primary sense of the word as used in speaking of fortifying a city, &c.

His name characterized the prince. He was the great reformer of Israel. He, in fact, created the Jehovah cultus in Judæa; he cleansed the temple; restored the service; destroyed idol worship out of the land; and was carried by his iconoclast zeal so far as to break to pieces and cast away beyond redemption the brazen serpent of Moses, preserved for centuries as a divinely precious relic and evidence of the exodus in the temple of Solomon. His sacrifices to Jehovah were on the most magnificent scale; and his restoration (if we may not call it his *invention*) of the great festivals made the whole people zealous for the law.

The Passover now first became national; and by the total destruction of all high places, Jerusalem became at last the only centre of convocation, and Mt. Moriah the only place of worship in the land.

He then reconquered the lost provinces of David's kingdom from the Philistines, and contracted an alliance with Egypt against Sennacherib, Emperor of Assyria. But he had to buy off the latter with all his spare treasures. By some unexplained accident Sennacherib's army was destroyed and Judah saved. On this being known, Hezekiah received a congratulatory embassy from his fellow-sufferer, Merodach Baladan, King of Babylon.

On the occasion of his hospitable and rather ostentatious reception of this embassy, the prophet Isaiah was greatly scandalized; so, at least, long subsequent chroniclers report.

The rest of his life was peaceful, and Judah became again prosperous. A reservoir was constructed west of the city, and conduits for a larger and more regular water supply added.

Man-asseh followed his father Hezekiah.

This pure Egyptian name follows immediately a pure Hebrew name; and, Idolatry follows immediately the most zealous Jehovahism. How is this to be accounted for?

Manasseh's mother's name was *Hephzibah*, חפציבה, *My delight is in her*. This is the poetical name given by the Second Isaiah (62 : 4) to *Zion*, and explains its own meaning. It may have been a term in popular use, taken from the young and beautiful queen of the pious King Hezekiah and applied to Jerusalem. Or, *vice versa*, Hezekiah may have endowed his wife with this pet name in reference to his own delight in Jehovah's delight in his (Hezekiah's) temper and work. But in any case Hephzibah

must have disappointed her husband's pious expectation; for, her son Manasseh was a Jehovah hater; reversed all his father's arrangements; re-established idolatry; erected altars to the solar and lunar deities in the courts of the Temple; degraded the priesthood, and slew the prophets.

Hezekiah's policy had been to ally himself with Egypt against Syria. It was unsuccessful, and he was saved by a mysterious disaster to the Assyrian host while it lay encamped in face of an Egyptian army.

Hezekiah's alliance with Egypt was no doubt permanent.

Did he marry an Egyptian princess?

This is not said; but neither is Hephzibah's parentage given. The name Hephzi-bah is suspicious. It is capable indeed of a plain Hebrew etymology; but the main element in it *Hapz, favor, delight,* is an exact translation of the *most common element in all the Egyptian royal and princely names, Meri, beloved.* The great Ramses was surnamed *Meri-n-Ra, beloved of the Sun,* or the *Sun's delight,* which would be translated into Hebrew *Hephzi-shemesh.** And a hundred other royal Egyptian names and surnames are constructed by composition with this same elemental *Meri,* applied to various other deities, like *Meri-n-Ptah,* Ptal's delight; *Meri-n-hathor,* Hathor's delight, &c.† It would be even possible that Hephtzibah, HPZI-BE may mean *Be's delight;* were any deity known named BE.

* The 36th King of the 2d Tablet Abydos is *Ra-meri, Sun's delight.*

† When Alexander's conquest grecised the Egyptian court language, the Greek φιλος took the place of this *meri* in official titles, and in comparative philology is its phonetic equivalent.

The first Ptolemy Lagidos was called *Soter,* "the preserver," by the Rhodians, grateful for his assistance against Demetrius.

His son, born in Memphis, educated by men of Egyptian learning, builder of Arsinöe and Berenice, completer of the great canal, constructer of the great high road across the Thebaid, founder of the Ethiopian colonial entrepôts, and restorer of Egypt to its ancient glory, was glorified by the natives as their great patron of the ancient learning. His library possessed 400,000 rolls. Callimachus, Euclid, Aristarchus, Aratus, Theocritus, Apelles, Manetho illustrated his court, compiled history, taught science and translated the Hebrew Bible.

The Egyptians gave him or he gave himself the surname *Philadelphus,* to express his ardent love for Arsinöe, his sister (and wife). But surely such a name would not have been adopted except in a land, the ancient monarchs of which had so often compounded their surnames, on the same principle, with the word *Meri,* "loving," or "beloved of,"—and usually some divinity. Arsinöe was Ptolemy's goddess, as Hathor had been of many an older native Pharaoh.

Ptolemy III, Euergetes, received his surname from the Egyptian priesthood, in reward for bringing back to their proper shrines a multitude of divine statues which Cambyses had carried off to Persia. He also loved and married his own sister Berenice, and revenged an affront to her by conquering Antiochus Theos, King of Syria, and then extended his conquests to Bactria and India. "*Well done* good and faithful servant," cried the priests, "thou shalt henceforth be called by the name of the last and greatest Pharaoh of the most ancient days, *Snefra,* Euergetes, the beneficent, the well doer, the benefactor. He also patronized the ancient learning. (See Lauth's Manetho; and the Prisse papyrus I, Ch. 2. line, 8.)

Ptolemy IV, Philopater, could not have been so called (except in derision) from his filial piety, for he was supposed to have poisoned his father. This wretch who murdered his own mother, wife, sister and brother, was called by

And there was not only a god *Bast*, in the Egyptian pantheon, but a curious deity named BES, said in one of the texts to have come from Arabia. This god presided over women's toilets, dress and ornaments, and was the especial favorite of the Egyptian ladies. The final ה in Hephzibah's name is well known as the equivalent of the sibilant (ʿαλς, sel, &c.) and *Hephzibah*, without any violence can be read *Hephzibes*. Her egyptian idolatry would then be not only pronounced, but natural and national.

There is no reason, then, for excluding solar and lunar proclivities from the characteristics of Manasseh's mother. Her son's practise would naturally revert to solar and lunar worship when he ascended the throne, which he did at the early age of six years (699 B. C.). For six years, at least, afterwards, he would be governed by the queen dowager and her friends; and by that time the religious reaction would have acquired stability. It is not surprising, then, that his diplomatic policy went wholly on Egyptian principles. The alliance which his father made with Egypt became still closer, and the story of the French restoration in 1815 was anticipated by the return of thousands of émigrés. These men, all of them devoted to Phœnician sun rites, and hating Jahvism, returned from exile at Memphis and San, Tyre and Sidon, hot with revengeful feelings against the orthodox cultus of Judæa, and charged with the religious sentiments prevalent among the vast Phœnician population of the Delta. It is not impossible that the name *Manasseh* was now first assumed by the young king as his banner name.

The supposition that the name was given him at circumcision, and that it was chosen because it had been borne by the eldest son of Joseph, and was one of the tribal names of Palestine, is improbable, 1. Because the tribes of Manasseh and Ephraim were hereditary enemies of the royal house of Judah, and 2. Because those two tribes had been deported to Assyria before this Manassah was born. It is *possible*, indeed, that *Manasseh* was a private name still in common use in the kingdom of Israel; but

the Egyptians *Typhon*, the devil; and by the Greeks *Gallus*, on account of his debaucheries, which brought his life to an end in its 37th year. But he paid great public honors to the *memory* of his father, and may have assumed the name Philopator, *Meri-n-tef*, as part of the hypocrisy.

Ptolemy V, coming to the throne at 4 years of age, and to the government at 14, assumed the title *Epiphanes*, the illustrious, equivalent to the name of the builder of the second pyramid, *Shafra* (Chafra), sunlight, the shining one. He then murdered the wise and faithful regent Aristomenes (who by the way carries *Menes* in his name like so many other Greeks), and had to suppress two insurrections against his tyranny. He hated his Syrian wife Cleopatra (the first), and courted the Romans, and was finally poisoned by his ministers.

Ptolemy IV, *Philometor*, again revives in his name the *Meri* of the monuments; but this time the source (or object?) of affection is not the father, but his mother Cleopatra, who ruled as regent from his 6th to his 14th year, and therefore whom he hated cordially. During his captivity in Syria, the Egyptians placed on the throne his brother—

Ptolemy VI, Euergetes II, called Kakergetes, evil doer, by the Alexandrians, and Physcon, from an umbilical hernia; who after various adventures ruled in common, with his brother, under the protection of the Romans. Ebers has laid the scene of his story of the Two Sisters in this double reign.

on this supposition it would become necessary to consider Hephzibah as an Israelitish woman married at the court of Jerusalem.

Manassah is spelled in Hebrew with four letters, מנשה, MNSE. But whether this be the mode in which it was spelled by the scribes of Hezekiah's court when his son was born, in 705 B. C., is as uncertain as whether the Masoretic pronunciation of the name in the third century after Christ approaches at all the sound of the name as uttered by King Hezekiah's courtiers. All we can go by is the Greek form *Μανασσῆς*, into which it was cast by the LXX at Alexandria or Heliopolis in the third or fourth century before Christ.

Jewish colonies were established in Egypt in the old age of the prophet Jeremiah, about 550 B. C. The traditional pronunciation of Manasseh's name was then only a century or so old; two centuries more could not have essentially altered it. If the Hebrew spelling, MNSE, were capable of a Shemitic explanation, which it is not, we might suppose the *Manassēs* of the LXX to be a modification of it under Egyptian literary influence. But it is quite as allowable to suppose that the A in MN[A]SE, or the A and S in MN[AS]SE, preserved by the Jewish scribes at Alexandria, were lost by the scribes at Tiberias or Babylon.*

The etymology of *Manasseh*, son of Joseph "who makes forget" from *Nasha* to forget, is absurd. It is given in Gen. 41 : 51 thus: "And Joseph

Ruling alone he married his sister (who had been his brother's wife also), and murdered her son in her arms on their wedding day. Afterwards he divorced her and married another Cleopatra, her daughter by his brother. His cruelties drove the Alexandrians into all other countries, whither they carried the arts, learning and religion of Egypt. He afterwards murdered his own son; was banished; restored; reigned long; was a great patron of letters, and called by some the Philologist.

Ptolemy VIII, Soter II, was immediately expelled by his mother and became king of Cyprus. Afterwards restored, but not acknowledged in the Thebaid, he reduced the great city of Thebes after a siege of three years to its present ruined condition. He was called *Lathyrus*, "a vetch," from a wart on his nose.

Alexander Ptolemy I, murdered his mother and was assassinated.

Alexander Ptolemy II was also assassinated.

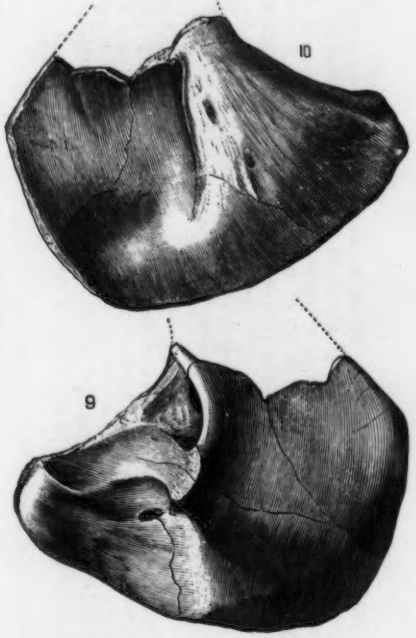
Alexander Ptolemy III was banished, and died at Tyre, leaving his kingdom to the Romans.

Ptolemy XII, *Auletes*, the flute player, received the names: *Philopator*, *Philadelphus*, *Neodionysus* (Osiris, the new Bacchus). He murdered 100 Alexandrine nobles, fled to Rome, lay concealed at Ephesus, and was restored to power by Gabinius, murdered his daughter Berenice, and died leaving orders that his eldest son and eldest daughter should marry and reign together, Pompey being their guardian. His queen was the last celebrated Cleopatra.

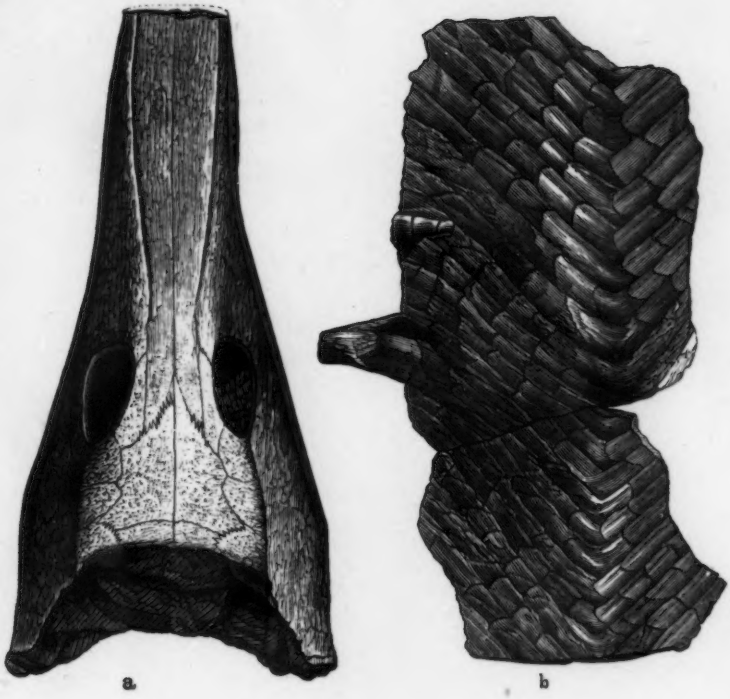
*Supposing the (Egyptian MN-ASSA) name to be presented for writing to a Jew scribe, he would have spelled it MNSA—MaNaS-A, and considered the duplication of the S unusual and unnecessary.

The fact that *Manasseh* (son of Joseph) is spelt in Hebrew (Gen. 41 : 51) MNSE like *Manasseh* (the tribal name, Josh. 13 : 29; 17 : 8) is of no moment, because wherever the name was found, its spellings would be made to agree. That it suffered changes in the course of centuries is rendered probable by the form MNSI in Deut. 4 : 43, "And Golan of Bashan of the Manassites," בבשׁן למנשׁי "in Bashan to Minash-i."

ERYOPS MEGACEPHALUS. Fig. 1, ½ nat. size. Figs. 9–10, 1½.

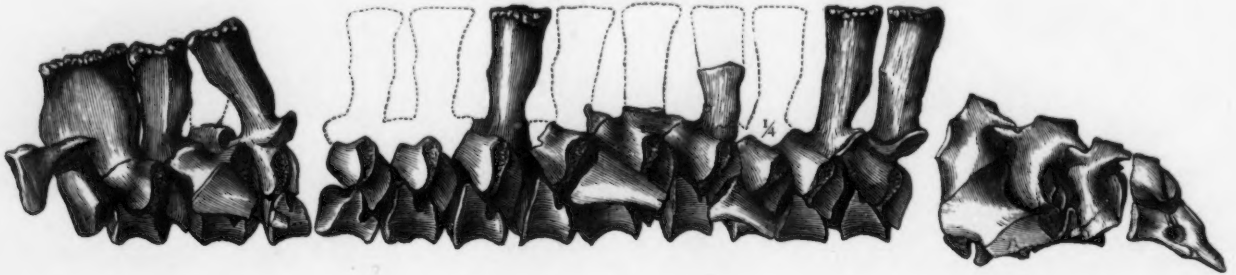


ERYOPS MEGACEPHALUS. Fig. 1, $\frac{1}{5}$ nat. size. Figs. 9–10, $\frac{4}{15}$.



a–b CRICOTUS sp. $\frac{1}{2}$.

2 ERYOPS MEGACEPHALUS. $\frac{1}{3}$.



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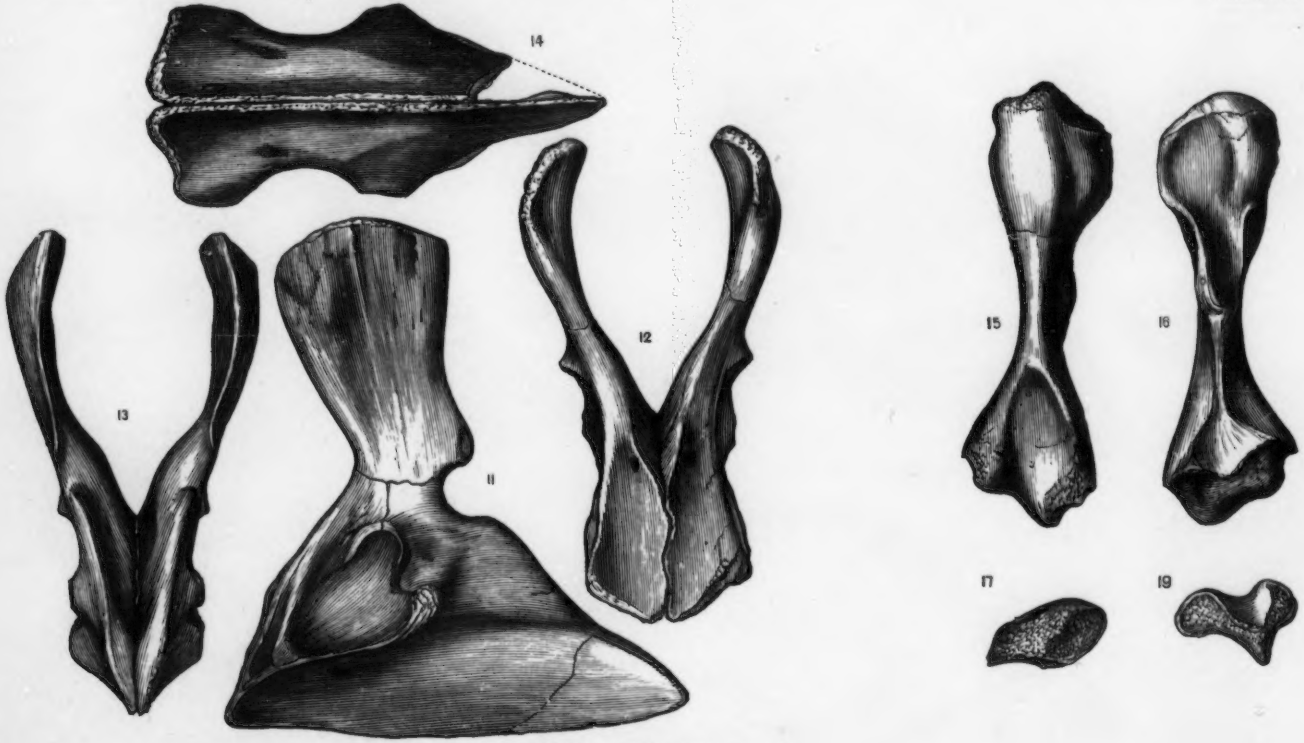
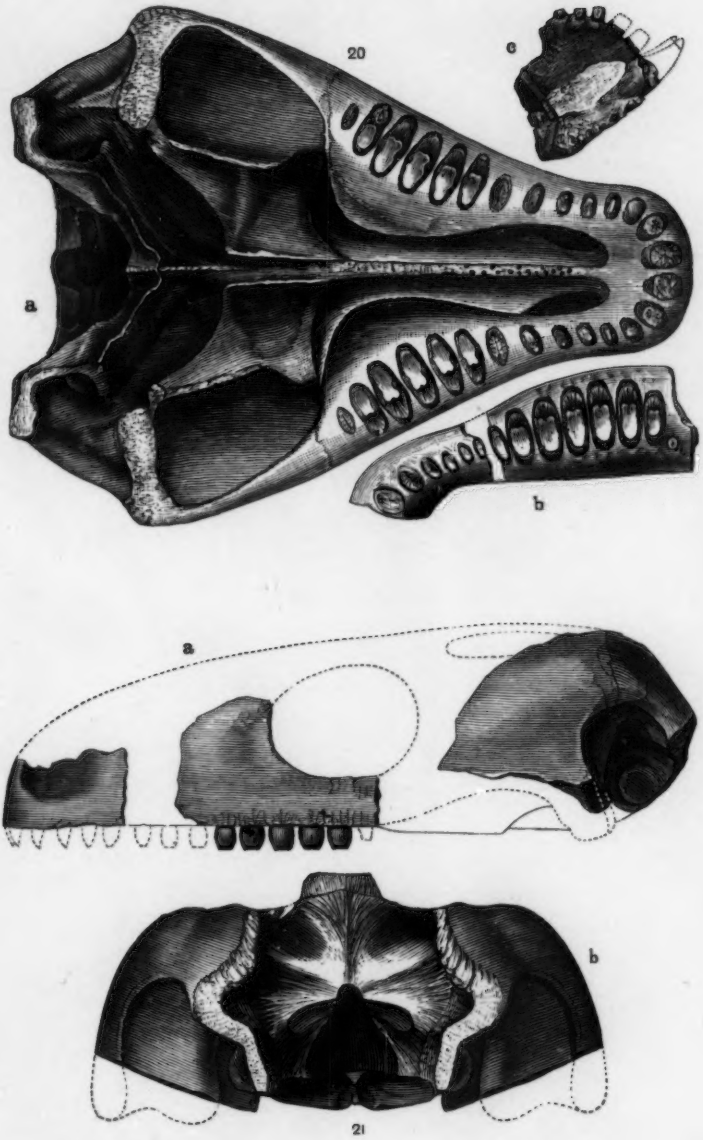
6

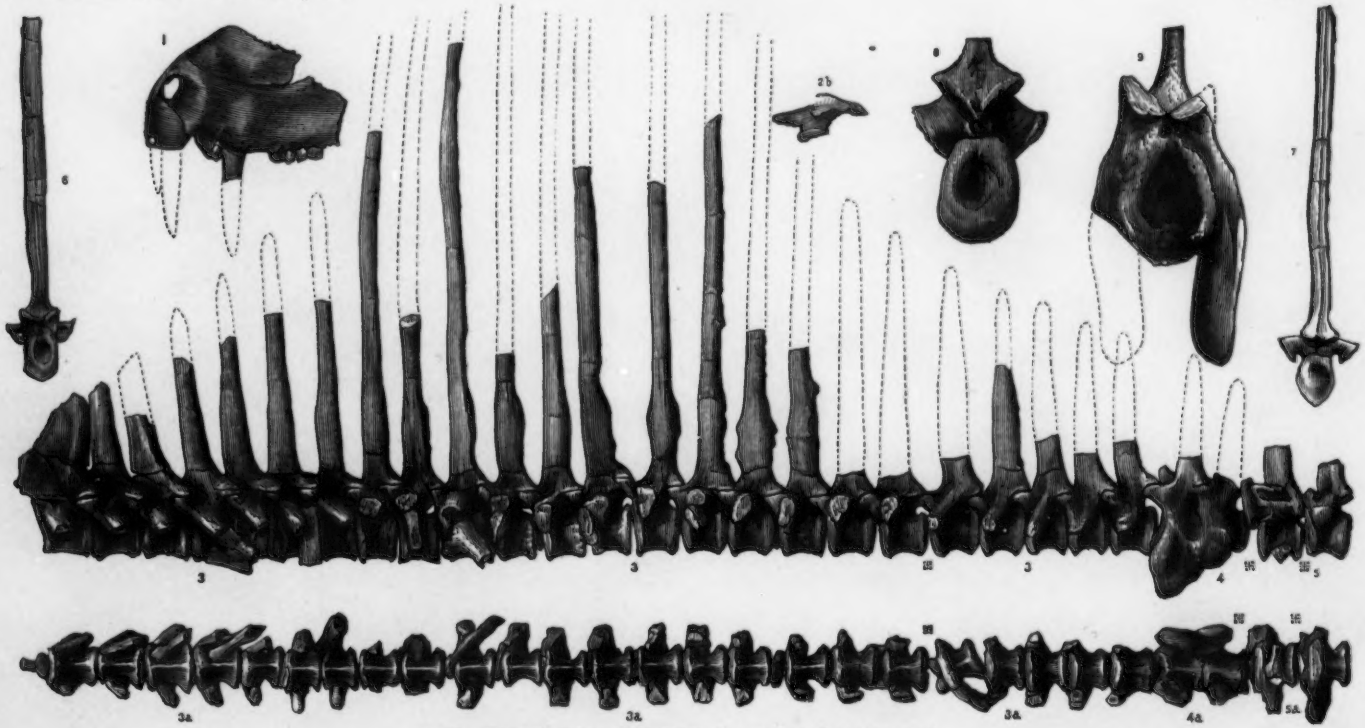
ERYOPS MEGACEPHALUS. ¼.



ERYOPS MEGACEPHALUS. $\frac{4}{15}$.



EMPEDIAS MOLARIS. $\frac{1}{2}$.



22–27 DIMETRODON INCISIVUS, $\frac{1}{4}$, except 8 and 9, $= \frac{3}{5}$.

EXTRACT FROM THE BY-LAWS.

CHAPTER XII.

OF THE MAGELLANIC FUND.

SECTION 1. John Hyacinth de Magellan, in London, having in the year 1786 offered to the Society, as a donation, the sum of two hundred guineas, to be by them vested in a secure and permanent fund, to the end that the interest arising therefrom should be annually disposed of in premiums, to be adjudged by them to the author of the best discovery, or most useful invention, relating to Navigation, Astronomy, or Natural Philosophy (mere natural history only excepted); and the Society having accepted of the above donation, they hereby publish the conditions, prescribed by the donor and agreed to by the Society, upon which the said annual premiums will be awarded.

CONDITIONS OF THE MAGELLANIC PREMIUM.

1. The candidate shall send his discovery, invention or improvement, addressed to the President, or one of the Vice-Presidents of the Society, free of postage or other charges; and shall distinguish his performance by some motto, device, or other signature, at his pleasure. Together with his discovery, invention, or improvement, he shall also send a sealed letter containing the same motto, device or signature, and subscribed with the real name and place of residence of the author.

2. Persons of any nation, sect or denomination whatever, shall be admitted as candidates for this premium.

3. No discovery, invention or improvement shall be entitled to this premium, which hath been already published, or for which the author hath been publicly rewarded elsewhere.

4. The candidate shall communicate his discovery, invention or improvement, either in the English, French, German, or Latin language.

5. All such communications shall be publicly read or exhibited to the Society at some stated meeting, not less than one month previous to the day of adjudication, and shall at all times be open to the inspection of such members as shall desire it. But no member shall carry home with him the communication, description, or model, except the officer to whom it shall be entrusted; nor shall such officer part with the same out of his custody, without a special order of the Society for that purpose.

6. The Society, having previously referred the several communications from candidates for the premium, then depending, to the consideration of the twelve counsellors and other officers of the Society, and having received their report thereon, shall, at one of their stated meetings in the month of December, annually, after the expiration of this current year (of the time and place, together with the particular occasion of which meeting due notice shall be previously given, by public advertisement) proceed to final adjudication of the said premium; and, after due consideration had, a vote shall first be taken on this question, viz.: Whether any of the communications then under inspection be worthy of the proposed premium? If this question be determined in the negative, the whole business shall be deferred till another year; but if in the affirmative, the Society shall proceed

to determine by ballot, given by the members at large, the discovery, invention or improvement most useful and worthy; and that discovery, invention, or improvement which shall be found to have a majority of concurring votes in its favor shall be successful; and then, and not till then, the sealed letter accompanying the crowned performance shall be opened, and the name of the author announced as the person entitled to the said premium.

7. No member of the Society who is a candidate for the premium then depending, or who hath not previously declared to the Society, that he has considered and weighed, according to the best of his judgment, the comparative merits of the several claims then under consideration, shall sit in judgment, or give his vote in awarding the said premium.

8. A full account of the crowned subject shall be published by the Society, as soon as may be after the adjudication, either in a separate publication, or in the next succeeding volume of their Transactions, or in both.

9. The unsuccessful performances shall remain under consideration, and their authors be considered as candidates for the premium for five years next succeeding the time of their presentment; except such performances as their authors may, in the meantime, think fit to withdraw. And the Society shall annually publish an abstract of the titles, object, or subject matter of the communications, so under consideration; such only excepted as the Society shall think not worthy of public notice.

10. The letters containing the names of authors whose performances shall be rejected, or which shall be found unsuccessful after a trial of five years, shall be burnt before the Society, without breaking the seals.

11. In case there should be a failure, in any year, of any communication worthy of the proposed premium, there will then be two premiums to be awarded the next year. But no accumulation of premiums shall entitle the author to more than one premium for any one discovery, invention or improvement.

12. The premium shall consist of an oval plate of solid standard gold of the value of ten guineas. On one side thereof shall be neatly engraved a short Latin motto suited to the occasion, together with the words: "The Premium of John Hyacinth de Magellan, of London, established in the year 1786; and on the other side of the plate shall be engraved these words: "Awarded by the A. P. S. for the discovery of ——— A. D.———" And the seal of the Society shall be annexed to the medal by a ribbon passing through a small hole at the lower edge thereof.

SECTION 2. The Magellanic fund of two hundred guineas shall be considered as ten hundred and fifty dollars, and shall be invested separately from other funds belonging to or under the care of the Society, and a separate and distinct account of it shall be kept by the treasurer.

The said fund shall be credited with the sum of one hundred dollars, to represent the two premiums for which the Society is now liable.

The treasurer shall credit the said fund with the interest received on the investment thereof, and, if any surplus of said interest shall remain after providing for the premiums which may then be demandable, said surplus shall be used by the Society for making publication of the terms of the said premium, and for the addition, to the said premium, of such amount as the Society may from time to time think suitable, or for the institution of other premiums.

The treasurer shall, at the first stated meeting of the Society in the month of December annually, make a report of the state of said fund and of the investment thereof.